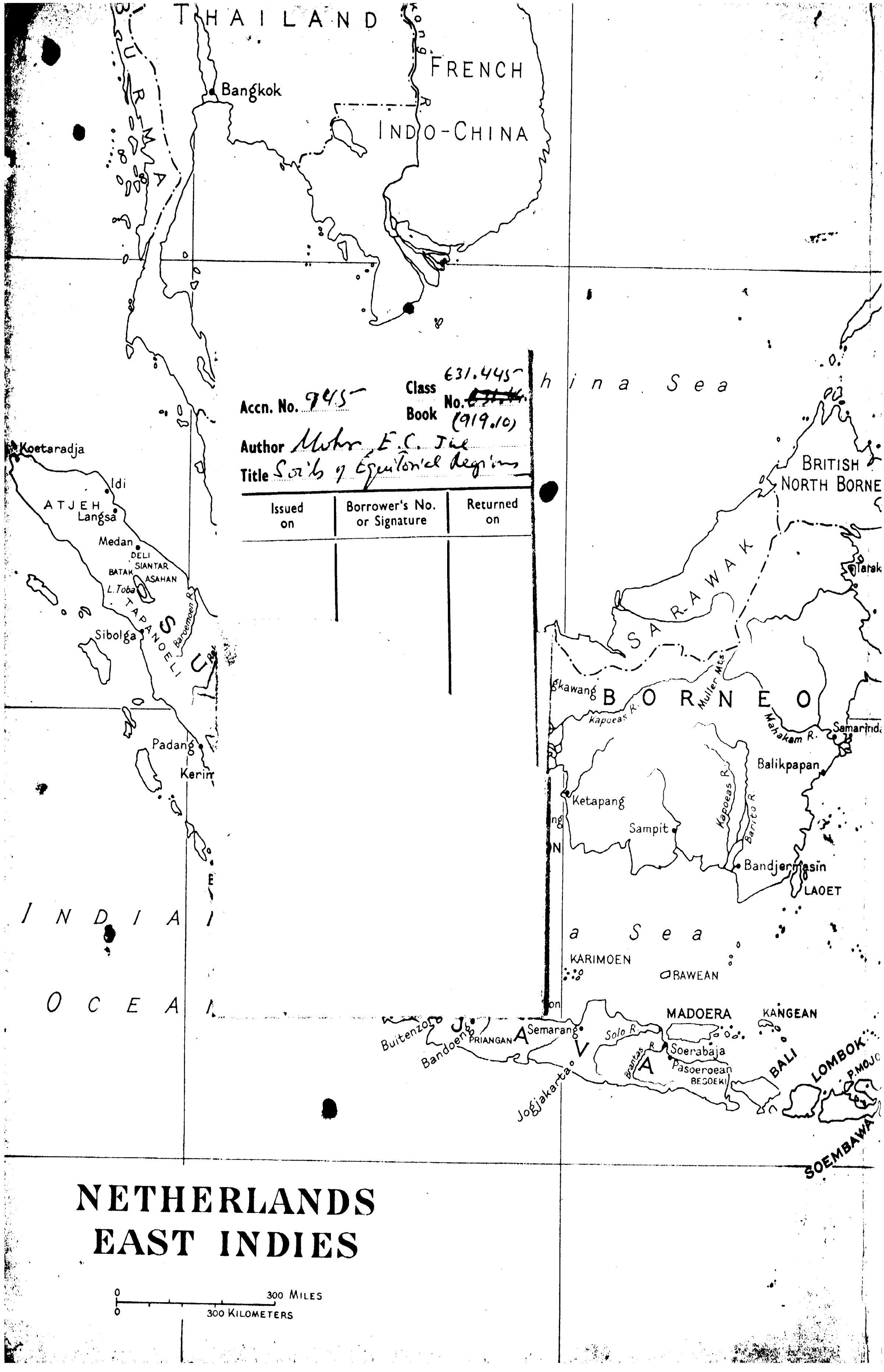


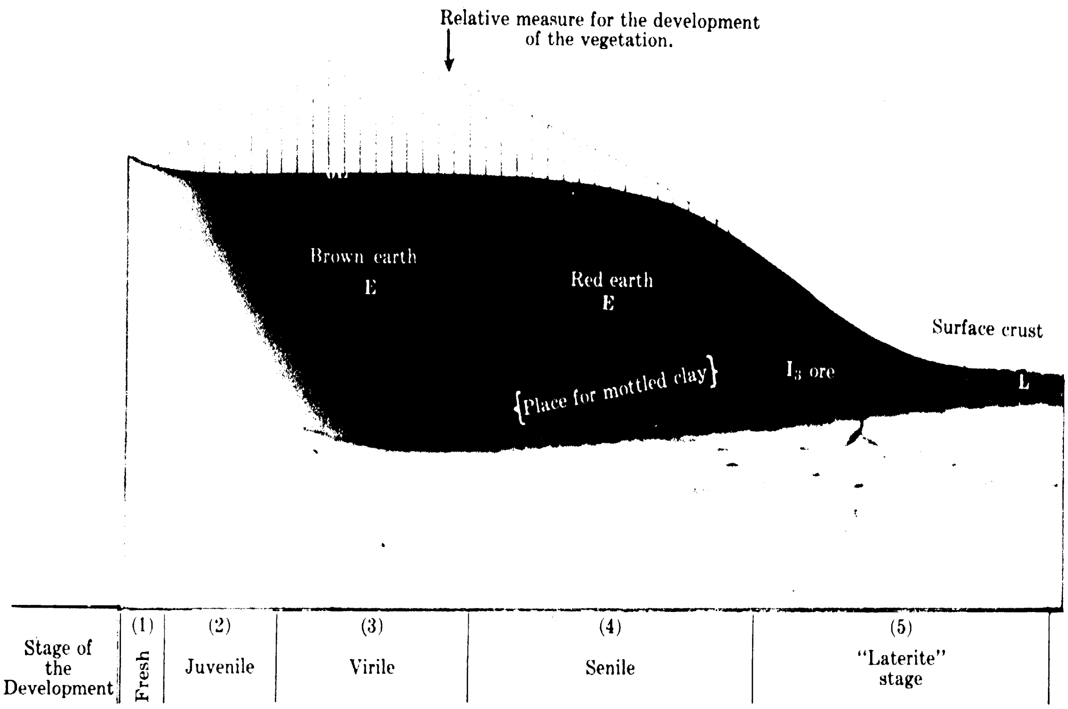
NETHERLANDS EAST INDIES

Manila
PHILIPPINES
PACIFIC
OCEAN
MINDANAO
SANGIHE
Manado
MINAHASA
Gorontalo
TERNATE
HALMAHERA
BATJAN
Paloe
Poso
Kolonodale
CELEBES
TORADJA
Malili
Palopo
Madjene
WADJO
Kendari
WOWONI
Sindj
Makassar
BOETON
MOENA
MOLUKKAS
BOEROE
CERAM
AMBOINA
BANDA
SALAWATI
Sorong
VOGELKOP
Manokwari
ARFAK MTS
JAPEN
Geelvink Bay
Sarmi
Mamberamo
MEERVLAKTE
Demta
Ho
Maccluer B.
Babo
Kokas
Fakfak
Kaimana
NEW GUIN
Wilhelmina-Top
Snow Mountains
Tanahmerah
Digoel
Okaba
Merauke
Arafura Sea
FLORES
PANTAR
WETAR
Ende
Atapoepoe
TIMOR
SOEMBA
Koepang
THURSDAY
Darwin
130°
AUSTRAL

THE SOILS OF EQUATORIAL REGIONS

WITH SPECIAL REFERENCE TO THE NETHERLANDS EAST INDIES

COURSE OF WEATHERING V.b.I. —He. (NN or Nr) ae (1/5).



A

COURSE OF THE WEATHERING al —He.Nr.am (1—4)

B

THE SOILS OF EQUATORIAL REGIONS

WITH SPECIAL REFERENCE TO THE NETHERLANDS EAST INDIES

by

Professor Dr. E. C. JUL. MOHR

AMSTERDAM
1933-1938

Translated from the Nederlandsch

by

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Office of Foreign Agricultural Relations
United States Department of Agriculture
Washington, D. C.

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FOREWORD BY THE EDITOR

The genesis, morphology, classification and use of tropical soils has received considerable attention in the literature; yet in spite of this attention much confusion still exists as to the real nature of soil formation and development in the tropics. It has been said that a part of this confusion is related to the fact that many of the studies on tropical soils have been conducted by workers whose main interests lie in the soils of the temperate zone. Their interest in tropical soils may have been stimulated by a hasty trip into the equatorial regions, and they have brought back samples for analysis which may or may not have been typical of the region from which they came.

Doctor E. C. J. Mohr, although a native of Holland, has spent an aggregate of many years in the Netherlands East Indies. He has travelled over essentially all of the islands and is thoroughly acquainted with their geology, soils, and agriculture. He can therefore be definitely classed as a long-time resident of the tropics and one who has been intimately associated with the soil problems.

Because so few English-speaking persons read the Dutch language, Doctor Mohr's writings have not been widely read in this country. With the rapidly increasing interest of American scientists in the Latin and South American countries, it will undoubtedly be of considerable importance to have available, in English, Doctor Mohr's data, experiences, and viewpoints on tropical soils as well as on their relation to agricultural use. The soil scientist interested primarily in the genesis, morphology, and classification of tropical soils will undoubtedly welcome the opportunity to become acquainted with Doctor Mohr's ideas.

The translator, Doctor Robert L. Pendleton, has had some twenty years of intimate contact with tropical soils, and, coupled with his intensive study of the Dutch language, is well qualified to make readily available to the English-speaking world this treatise on the soils of the Netherlands East Indies.

Cornell University
Ithaca, N.Y.
February 22, 1943

TRANSLATOR'S NOTES

That there are outstanding differences between certain soils in temperate regions and certain other soils of equatorial regions cannot be denied. To continue, however, to think of tropical soils as an entirely separate group is as great a mistake as to consider the soils of humid temperate regions separately from soils of arid temperate regions. Since, however, the soils as a whole of equatorial regions have been so inadequately described, there is great need of making more easily available such literature regarding them as does exist.

The contributions by Professor Mohr to the description and interpretation of the nature and of the development of equatorial soils are outstanding. This is without doubt because of the fact that after spending some years in the Netherland East Indies in the study of the soils of that enormous and varied equatorial region, Mohr had the good fortune to visit Dr. Hilgard in California. Mohr caught the significance of Hilgard's discovery of the effects of climate upon soils, a discovery which Hilgard had made independently of the similar Russian discoveries. Upon his return to Insulind, Mohr proceeded to use Hilgard's theory to explain the reasons for the existence of the exceedingly diverse soils which are found in this equatorial region. Thus was laid the foundation for Mohr's refreshingly different discussion of tropical soils which I translated and issued in mimeographed form in 1929 for the use of my students in the College of Agriculture, University of the Philippines. After Professor Mohr had checked and revised that translation, it was later (1933) published in Peiping by the National Geological Survey of China with which I was then associated.

Soon thereafter the Colonial Institute of Amsterdam published the first part of Professor Mohr's much more comprehensive treatise on equatorial soils. From time to time there appeared five additional parts of this work:

De Bodem der Tropen in het Algemeen, en die van Nederlandsch-Indië in het Bijzonder. door Dr. E. C. Jul. Mohr.

Deel 1

Erste stuk (1933) pages 130.

Tweede stuk (1933) pages 131-335. Colored plates 2, half-tones 40, map and sketches 5.

Deel 2

Erste stuk (1934) pages 142. Half-tone plates 66, sketches 3.

Tweede stuk (1935) pages 143-342. Half-tone plates 34, sketches 6.

Derde stuk (1937) pages 343-572. Half-tone plates 35, 1 map.

Vierde stuk (1938) pages 573-816. Half-tone plates 59, 1 sketch.

Koninklijke Vereeniging Koloniaal Instituut, Amsterdam.

Mededeeling 31, Afdeeling Handelsmuseum No. 12.

Gradually, as opportunity has offered, I have worked at an English translation. In the earlier part of this work I had the assistance of my former teacher, Mrs. Ine Mann der Hollander. In the last few years it was necessary to push on with the translation unaided. Hence there are, doubtless, inaccuracies in the rendering, particularly of colloquial expressions. Moreover, because it seemed advisable to follow the original as closely as possible, it has been impossible to avoid a certain lack of smoothness in the rendering into English

I am grateful both to Dr. B. M. Gonzalez, Dean, College of Agriculture, University of the Philippines, and to Pra Chuang, Director-General, Royal Department of Agriculture, Bangkok, Thailand, for permission to use official time to continue this translation.

Both the Colonial Institute and Professor Mohr were most generous in granting permission for the publication of this English translation. The Institute even offered the use of the original half-tone and color blocks for use in the English edition. Unfortunately, the turn of events in Western Europe completely interrupted communication with Professor Mohr shortly after I received a letter from him from his home at Santpoort, near Amsterdam, stating that he was actively engaged in the checking and revision of my translation, and that he was expecting to rewrite certain portions of the general discussion to bring them fully up to date; if this project could have been carried to completion this English version would really have been a new book and not a mere translation.

Since further collaboration with Mohr has been impossible, and may continue to be so for a long time to come, this translation has not had the benefit of his checking and revision. It is hoped that any inaccuracies in the rendering will be pardoned, and it is also hoped that when peace at last returns it will be possible to renew contact with Professor Mohr and that a revised edition of this English version can be published.

Robert L. Pendleton

Central Agricultural Experiment Station
Bangkhen, Bangkok, Thailand (Siam)
October 7, 1940

By the fall of 1940 the censorship to which all written communications, maps, and photographs from Thailand were being subjected was so severe that there appeared to be little chance of this manuscript and the original publication getting through. At that time, of course, we did not imagine that we would be interned in Bangkok for many months in 1942, and did not guess that there would be practically no possibility of bringing out manuscripts with us when we did come. I am therefore deeply indebted to Dr. Douglas R. Collier, of the Presbyterian Hospital, Chiengmai, Thailand, who, in spite of great inconvenience to himself, in October 1940 gladly undertook to bring a copy of Mohr's book in Nederlandsch and the manuscript of this translation with him to the United States. This English edition is evidence enough that he was successful in his struggles with the censors!

To Dr. Richard Bradfield, Head, Department of Agronomy, and to Dr. Robert F. Chandler, Jr., Associate Professor of Forest Soils, both of Cornell University, I am particularly indebted for the great amount of time and effort they devoted to editing this translation.

And in conclusion I wish to express my gratitude to Mr. Ralph H. Allee, Chief, Division of Latin-American Agriculture, Office of Foreign Agricultural Relations, and to Mr. J. W. Edwards, of Edwards Brothers, Inc., Ann Arbor, Michigan, who have made possible the publication of this translation in spite of unusual difficulties. I am also grateful to Mr. E. C. Lawson and others of the Department of State who have enabled me to do most of the proof reading while stationed in Central America.

Robert L. Pendleton

Managua, Nicaragua
1 September 1943

CONTENTS

1. In the spelling of place names the original Nederlandsch form has been retained. The chief difference between this and English usage is that the former uses "oe" where the English spelling would replace this by "u" or "oo"; "oe" should always be pronounced as the "oo" in "shoot."

PART II. THE SOILS OF THE NETHERLANDS EAST INDIES

INDEXES

FOREWORD

During the last century in Europe, and in the last half century in North America, research has done much to increase the knowledge of the soil. The results of all this work have been published in all sorts of books and journals; but, because the soil is a subject with which not only agriculture but also numerous other industries, professions and public services have to do, that literature is cut up quite beyond measure into little bits and appallingly scattered.

It gradually became more and more impracticable, without spending a disproportionate amount of time and trouble, to study up on the literature of any one subject or another concerning the soil in order to be properly informed as to the status of the subject.

The generally felt need of freeing oneself from the necessary obligations of every time commencing from the beginning regarding everything which had been recorded on one subject or another in soil science has been the cause of the preparation by E. Blank of the "Handbuch der Bodenlehre" published in 1929-1932 in 10 good-sized volumes.

But although that work in many respects is an admirable whole and contains a wealth of things worth knowing, which may be easily and quickly located--yet the tropical regions are very inadequately treated in that handbook. This is not strange, because of the many soil scientists and other researchers who have assisted in the preparation of the Handbook, only a few have lived for more than a short time in the tropics and there gathered scientific knowledge of the soil.

Thanks to the very intensive study, especially of agriculture, in the last quarter century, and properly speaking even much longer, something similar has come about in the tropics and particularly in the Netherlands Indies, as was mentioned above as taking place in Europe and in the United States of North America. Very considerable is the number of observations and investigations carried out upon the soils of the Netherlands Indies and very widely scattered in a considerable number of publications, which for the greater part were published in only limited editions and are therefore difficult of access for the present-day workers and will be much more so for the coming generations. Many researchers, especially those who are carrying out work on soils, particularly in the Netherlands Indies, will experience this difficulty.

Thus it seems desirable to gather together all those loose bricks and stones, those uncorrelated and scattered papers, some of which may at times be found only with difficulty, and to begin to raise up out of them a complete structure. In other words, out of all this knowledge about the soil, which up to the present time is so alarmingly scattered about, an endeavor should be made to put together such a publication, so that the investigators of the soil in the immediate and more distant future, need no longer feel obliged, at least not to the same extent, to dig up and to sort all the earlier publications but, with this book as a guide, might be able to decide what for him seems to be essential and of value.

It would of course seem logical that such a handbook ought to be written in the region to which it especially applies, that is, in the Netherlands Indies themselves, for nowhere else are to be found the data for it so well as there. Yet that is not entirely correct, since those who in the Netherlands Indies as a result of their actual work may be thought to be in a position to write such a book frequently have their days so crowded, are so much engrossed, that in spite of the best intentions it would be quite impossible for them to find the time necessary for such a task. Consequently such tasks must be left to those who have been pensioned after their repatriation.

When then at the suggestion of the Director of the Commercial Museum Section I was instructed by the Administrative Council of the Colonial Institute to write a book on the soils of the Netherlands Indies, there was granted in connection with my temporary deputation to the Experiment Station of the Java Sugar Industry, an additional few months for travel in those portions of the Netherlands Indies which during my official travelling (up to 1920) were still unknown because I had not seen them myself and which also were still very inadequately explored pedologically. Although from the beginning the difficulties of this task were by no means under-estimated, I assumed that commission with pleasure.

Without exception all sorts of Bureaus, organizations, and individuals with whom ideas were exchanged about the plans accepted the suggestions; and even more than that they agreed to coöperate. It was a pity that the circumstances of the financial crisis, and the resulting retrenchment in personnel and budget in the Indies, made it possible to make good the promises only to a very limited extent, and it is apparent that in the immediate future not much improvement is to be expected. This is very much to be regretted, for as is typical of all things human, this work, even before it has been commenced has been rendered much less perfect and still more incomplete than it might otherwise have been.

There is however this consolation both for the reader and for the writer, namely, that this book is not intended to be a culmination--it is not a principal station along the possible road of soil science; it is, at most, a junction station along this road from which point many kinds of lines run out, which in their time will be further developed by others.

* * * * *

Now as to the contents of this book: the logical and, therefore, perhaps also the indicated divisions might be as follows: having begun with (1) the presentation of mere observations, thus with those matters which might be called an <u>objective description</u> of that which is to be seen and noted with reference to the soil in the tropics, particularly in the Netherlands Indies, then (2) to follow up with the general conclusions which are to be deduced from these observations, thus to build up the <u>relationships</u>, the <u>science</u>, and (3) finally to go once more through the whole field of observed facts, explaining them with the help of the general points of view which have meanwhile been obtained.

There are, however, difficulties in handling the material in this way. <u>In the first place many</u> of the readers have already had at least some tropical experience; for them an introductory description by itself does not have any of the attractiveness of novelty, hence the interest of the reader would be very apt to rapidly slaken. <u>Secondly</u>, an objective description is difficult to render; in spite of everything every writer soon develops his own conceptions, his own plan of action, and so is well nigh unable to avoid giving great weight in his writings to some qualities which later may appear to be of subordinate value; on the other hand he may leave out of his descriptions other less conspicuous peculiarities of the soil, though later these may prove to be of essential importance.

Because of these reasons that line of action was not chosen but rather I decided to start this book with the point of view that there is already available factual material that is extensive and known to many, from which the <u>beginnings of a tropical soil science</u> have already begun to be worked out. Hence even though many important gaps must be pointed out we start with the explanation; moreover many hypotheses have been stated which probably in the opinion of certain readers as in my own, cannot plead freedom from a certain speculative element. However, it seems to me that it is better to state at once the most probable hypotheses, so that they may be criticized and further studied than that we say nothing about them.

FOREWORD

After this general part there follows a regional description of the soils of the Netherlands Indies, in the course of which in a number of special cases, the general points of view are set out, and both confirmation and debatable points are indicated.

In this way, I hope I have achieved a rounded understandable treatment of the subject. In this I hope I have not been mistaken, and at the same time have succeeded in inspiring younger investigators to undertake with, if possible, even more zeal the further investigation of the soils of the Indies. Only if this result be achieved shall I consider myself happy and successful in this work!

Amsterdam, December, 1932.

Part I

GENERAL CONSIDERATIONS

Chapter I

THE POINT OF DEPARTURE: THE ROCKS WHICH SERVE AS PARENT MATERIAL FOR SOIL FORMATION

1. GENERAL CONSIDERATIONS

Practically speaking, all soils originate from solid or more or less ground up rocks, which have either remained in place or which have been transported. And rocks are composed of minerals, seldom of only one, almost always of many kinds of minerals. The minerals are recognizable either by their distinctive method of crystallization, or by their form, color, or a number of other characteristics. Among the characteristics which interest us there are especially the following: the manner in which the minerals react to weathering influences--to the factors of soil formation. In the field of soil science we are concerned primarily with the mineral composition of rocks, especially since each mineral goes through a characteristic weathering process. From the standpoint of soil science, provided that the mineral composition is the same, it is of no consequence whether, for example, a certain limestone is of the chalk age or belongs to the Miocene; or whether a certain granite is PreCambrian or Neocene. Historical geology is of significance for soil science only in so far as it is related to petrology, the science which deals with rocks and their minerals. This is of course not denying the fact that a certain place on our earth has had a certain history, and therefore at that place certain kinds of rocks have been formed in certain geological historical periods. To him who knows that relation, a historical geological designation frequently stands out and enables him to recognize immediately the presence of a certain group of rocks. However, this is not always the case. Therefore, one quite often finds in colloquial expressions such contradictions as: young volcanic rocks contrasted with Tertiary formations, or worse still, young volcanic soils as contrasted with Tertiary soils, expressions which can be considered inaccurate in their uncertainty.

After what has been said, the reader might now expect that we would commence by dividing the rocks according to their mineral composition. If, however, we first start with a division according to the method of rock formation, the reasons are: 1st that the methods of formation may be surveyed at a glance, and 2nd, as it will appear, at the same time the methods of formation also determine the mineral composition. In fact, in petrology this is the only way to approach the subject.

These then are the reasons for first making the following division of the rocks into the broad groups:

A. Rocks which as such have solidified from an extremely hot liquid state, the congealed or igneous rocks.

B. Rocks which as such are made up of and have become solid from previously incoherent yet in themselves already solid fragments and particles, brought together and deposited from water or from air: the sedimentary rocks. Besides these there is also the following group:--

C. Rocks originating from rocks of group B and possibly also from group A, as a result of the action of high pressure, accompanied as a rule by high temperature over a long time, so that even without melting a recrystallization to new minerals can occur, and properly speaking all characteristics of the rock are altered, barring an unusually maintained stratification: the metamorphic rocks.

Let us first consider the igneous rocks.

It is self evident that the formation of these rocks cannot be considered in detail.[1] In connection with weathering only a few points demand mention; these will be taken up subsequently.

Very deep, sometimes kilometers beneath the earth's surface is found the "stove" in which is the glowing liquid mass, called the magma. Through causes which need not be considered here, the magma is forced upward, through one or more fissures, and comes out at the surface. Then either one of the two following things may happen:

1. The magma may flow out quietly and by cooling congeal as lava. This is a collective name for all such rocks, for since no matter how much they sometimes differ among themselves, all have solidified in the same manner.

2. The magma may not flow out quietly. This is because of the enormously high pressure to which the magma is subjected. Deep down in the earth there are, notwithstanding the high temperature, gases dissolved in the magma. If such gas-laden magmas are forced to the surface where there is but one atmosphere of pressure, one can easily understand that the whole viscous liquid enormously expands and in extreme cases is exploded to dust-fine droplets. Examples of this are the awful explosions of the Kloet in 1901 and 1919 which terrified the whole of Java.

Drops of magma, especially the tiny dust-fine droplets, flying through the air congeal very quickly, in a matter of minutes, solidfying to glass, for the constituents have no time to crystallize. Time is quite necessary for the formation of crystals, this is more so when originating in viscous liquids. A lava stream cools very slowly. The length of time required depends upon the thickness of the flow, and may continue for weeks, months, or even years. Hence as is well known crystals can grow in lava flows, though even much of the material congeals to glass. The magma which remains stationary in the crater pipe and that which has been injected into the lateral fissures cools still more slowly. As a consequence, relatively more crystals should form, with a correspondingly smaller quantity of glass. Finally, at still greater depths, where the main magma mass remains at rest, cooling off occurs so slowly that the congealing takes centuries; in such cases the resulting rock is completely crystalline.

It is a well-known phenomenon that, whether simply in a solvent, or in a liquid which chemically attacks the molecules of the crystals, the solution of crystals takes place more slowly and with greater difficulty if the crystals are large, homogeneous and pure, than when they are small, impure and full of inclusions. One can also say that the speed of solution or attack by the solvent is proportional to the contact surface, hence when one wants to quickly dissolve crystals, he grinds them fine in a mortar, and if one brings into contact with the solvent the same material as that of which the crystals are formed, but in the colloid state, the solution takes place still more rapidly.

If we apply this theory to the rocks referred to, then the weathering which is caused by the water which circulates in contact with the rocks, must more quickly attack 1st the finely divided rocks--i.e., the blown-out ash, the sand and the porous pumice stone, than the hard and compact rocks; and 2nd more quickly attack the amorphous colloidal glass-containing volcanic rocks than the deepseated rocks consisting of massive, hard, homogeneous crystals.

Consequently, a genetic classification of the rocks according to the depth and the method of their formation gives at the same time a classification according to their weatherability. This is of great significance in soil formation.

Therefore the rocks which have congealed from the liquid state, the magmatic or igneous rocks, may be classified as follows:

a. rocks which have solidified deep in the earth, the plutonic rocks
b. rocks which have solidified on their way to the surface of the earth, the intrusive rocks
c. rocks which were still fluid when

---

1. For this the reader might refer to the handbooks on petrology and geology. For example, the Nederlandsch works: B. G. Escher, De Gedaanteverwisselingen der Aarde (Wereldbibl.); L. M. R. Rutten, Voordrachten over de Geologie van Nederlandsch-Indië, Groningen, 1927.

they reached the earth's surface and only then became solid: the <u>volcanic rocks</u>, which may be subdivided again into <u>outflowing or effusive rocks</u> and <u>blown out</u> or <u>efflata rocks</u>.

Consequently from one and the same magma there can exist three kinds of rocks, with, of course, all kinds of transitional forms: rocks which, with the exception of small differences caused by the escape of volatile constituents, have the same total chemical composition, but with very different mineralogical composition and physical nature, and consequently with very different weatherability.

A second point which now invites attention is that the magma which arises from the depths of the earth is by no means always the same, but may be very <u>different in chemical composition</u>. The result of this diversity is that upon congealing a great variety of minerals crystallize: moreover, these minerals occur in the rocks in very different relationships. Judging them according to the mineralogical composition, the number of rocks that occurs on the earth, or even only those met with in the Netherlands Indies, is appallingly great.

Nevertheless--it appears upon a closer view that, although almost all the known 100 chemical elements are present in rocks, yet in most rocks only a scant dozen of them play a definite role in determining the character and behavior of the rocks. For our purpose provisionally we can leave the rest of the elements out of consideration.

It appears further that of the few hundred known <u>minerals</u>, again only a small number of them occur in the rocks in a sufficient quantity for us to here take cognizance of them with reference to the soils of the Netherlands Indies.

With this in mind, a relatively simple diagram can now be drawn up, wherein may be united in a comprehensive whole the principal elements and the principal minerals formed from them (see Fig. 1).

In the central column are the oxides of the elements in four main groups, with an additional group:

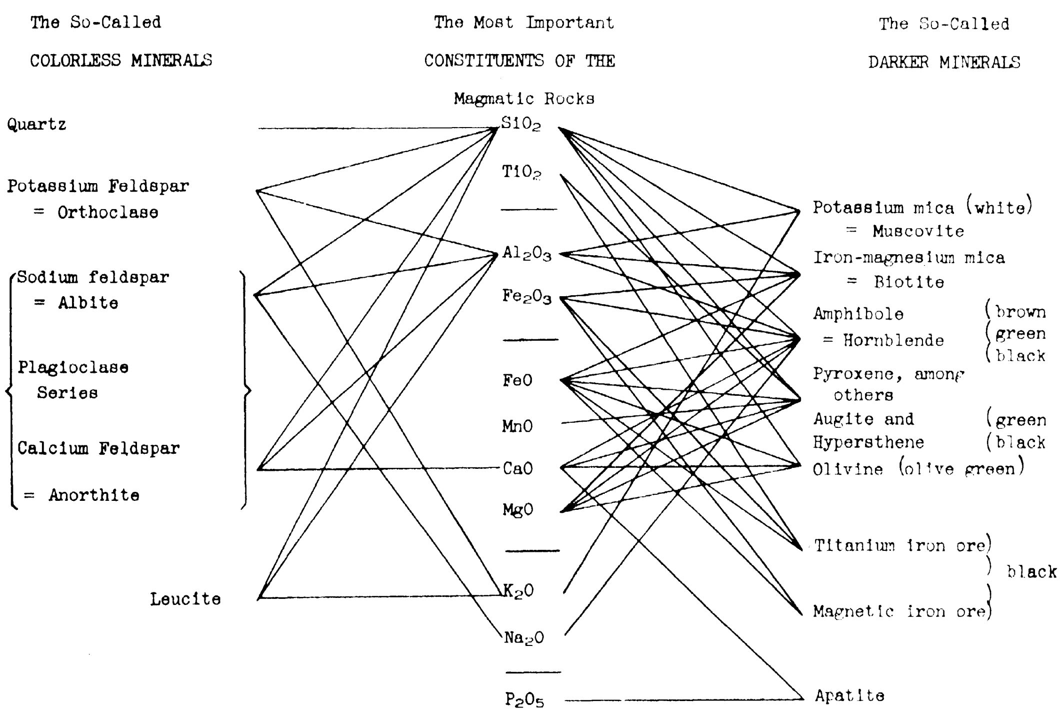

Fig. 1

a. The acids:
  silicic acid
  titantic acid
b. the sesquioxides:
  aluminum oxide
  ferric oxide
c. the bivalent bases:
  ferrous oxide
  manganese oxide
  lime
  magnesia
d. the alkalies:
  potash
  soda
e. the additional group:
  phosphorus
  sulfur
  flourine
  water

The groups a, b, c, and d form quantitatively already 96.7% of the average of all magmatic rocks[2]; the group e, totalling but 3.3% of which 1.9% is water, includes all those elements which, quantitatively it is true, exist in very small amounts, but which qualitatively play an important role in living organisms; from that point of view they must receive adequate consideration.

In the above scheme the principal minerals are found in the columns at the right and the left. At the left are the so-called colorless minerals though nevertheless a few are somewhat colored; and at the right the so-called darker minerals of which some are colorless. A rough estimation by F. W. Clarke,[3] including about 700 igneous rocks, gives for the average mineralogical composition of the rocks:

Quartz	~ 12%
Feldspars	~ 60%
Amphiboles and pyroxenes	~ 17%
Micas	~ 4%
Other minerals	~ 8%

Calculated for the world as a whole, the minerals which stand in the left hand column of the table are far in the majority; the feldspars alone already make up more than half. Meanwhile for the rocks of the Netherlands Indies, at least for the soil-forming rocks of Java and a number of the more easterly lying islands, one would presumably obtain a somewhat different picture: with less quartz and more "dark minerals." But more about that later.

Here the emphasis should be placed on the fact that the number of rock-forming minerals is only about a dozen, to which one must add the glass which has not crystallized. But at the same time it should be mentioned that there usually occur in each rock only a few of the dozen mineral types, so that with the exception of the accessory minerals each case is very simple from the mineralogical and soil-forming standpoints.

Moreover, relative to the chemical and mineralogical composition there is, in general, still another point which is of significance in soil formation.

If one classifies the magmatic rocks observed on the earth--apart from the peculiarities with which we are not concerned and which are here left out of consideration--into one series according to the content of silicic acid then we find that the lowest figures for silicic acid lie below 50%, the highest about 80%. Mineralogically that makes a great difference, because the other elements in the same series also exhibit a certain division; one finds for example, in general, together with:

much silicic acid	little silicic acid
relatively much aluminum	relatively much iron
relatively much potassium	relatively much magnesium
	relatively much calcium
	relatively much phosphorus

Mineralogically this difference is expressed in the following manner:

much silicic acid	little silicic acid
Much quartz	No quartz
Potassium feldspar	Calcium-sodium-feldspar
Little of the so-called dark minerals such as: mica hornblende	Much of the so-called dark minerals such as: hornblende, augite, hypersthene, olivine, magnetic iron, titanium iron;
Colorless, iron-free glass	Darker, iron-rich glass

2. F. W. Clark, The data of geochemistry, U. S. Geol. Survey Bull. 695, (1920), p. 28.
3. F. W. Clark, The data of geochemistry, U. S. Geol. Survey Bull. 695, (1920), p. 32.

Now this difference also stands out clearly in the weatherability of the minerals. Quartz practically does not weather at all. Potassium feldspar weathers with much more difficulty than the calcium-sodium feldspar; the latter weathers more rapidly, if the calcium/sodium ratio is high. In the series of dark minerals: mica, hornblende, augite, hypersthene, and olivine the weatherability increases from the first to the last mineral. Dark iron-rich glass weathers much faster than colorless glass. In short--practically all the mineral components of the rocks poor in silicic acid weather faster than those of the rocks rich in silicic acid.

This will be seen to have many consequences in soil formation. For example we know that the rapidly weathering rocks will give rise in a relatively short time to a soil upon which vegetation can develop, which, in turn has a great influence upon the further course of weathering. Under tropical rains the weathering preceeds the erosion and the chemical leaching out. On the other hand with rocks which weather with difficulty, the chances are great that weathering and soil formation cannot keep up with the loss of soil through erosion and the impoverishment of the soil through leaching out, so that entirely different and less favorable conditions for vegetation must prevail. More about this later on.

Among the two lines developed above, namely, the manner of congealing and the content of silicic acid, there may now be drawn up the following scheme of magmatic rocks (drawn in broad lines, and leaving out those rocks which are not found in the Netherlands Indies, or which do not occur there in significant amounts) (see Fig. 2).

If one should arrange on a table a number of hand samples in accordance with this scheme, it would be apparent at a glance how from left to right the color

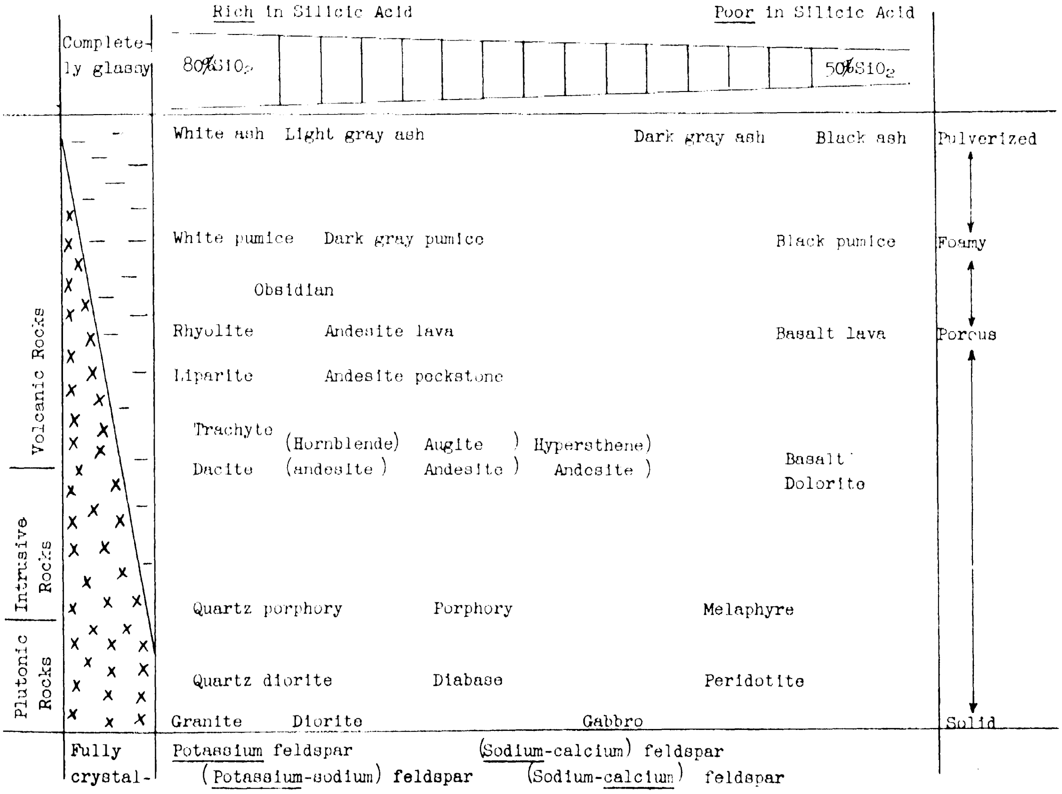

Fig. 2

changes from light to dark, and how at the same time from above downward the density and hardness of the rocks increase.

Incidentally, in connection with the scheme proposed above, the age of the rocks may be mentioned here. It is obvious that the magma from which the still active volcanoes continue to build themselves up, has not been fully used up; in other words, along with the recent volcanic rocks belong intrusive and plutonic rocks which probably are not yet even solid and cold, but which are inaccessible at the depths where they now occur.

A great deal must happen geologically before plutonic rocks lie exposed at the surface of the earth. To make this possible, much time is necessary for the folding of the crust of the earth and for the weathering away of the layers lying above. In order for plutonic rocks to have become accessible to us, they must be relatively old. Along with the plutonic rocks--effusive rocks, lava, and volcanic ash also occurred. The longer ago those processes of formation occurred, the longer the processes of weathering went on, in order to break the rock up and as such to cause it to vanish. And now--taking into consideration the stronger weatherability of the more porous effusive rocks etc., and at the same time the greater susceptibility to attack of the products which have less silicic acid, (the more basic products)--it may be said that out of those older formations the ash, pumice stone and lava have certainly, to a great extent, weathered away, and of the solid effusive rocks the more acid, i.e. those richer in silicic acid, have survived the longest, and consequently are the most prominent today.

It is an obvious fact that among the visible magmatic rocks a larger proportion of the geologically oldest should on the whole be plutonic rocks, that is, toward the acid side (granite), while the youngest must practically all be volcanic, and must exhibit those more porous forms with a relatively greater percentage of them on the basic side.

This by no means fully exhausts this subject. However, the problems of the differentiation of magmas; the question as to whether in the course of geological history the magmas, which have become rocks, became on the average less rich in silicic acid and thus more basic; the question as to whether in some portion of the earth, for example, around the Pacific Ocean, more basic magmas emerge than elsewhere, etc., will not be gone into further here; we leave these questions to the petrologists.

* * * * *

Following the above short general mention of the igneous rocks, a few things may now be mentioned about sedimentary rocks.

More properly these rocks, at least as far as their formation is concerned, might better be discussed after the chapter regarding the formation of the sediments, from which they have originated. However, seeing that weathering and soil formation affect both magmatic and sedimentary rocks, we here intentionally introduce the cycle in nature with a further stage, the sedimentary rocks, as they are exposed to weathering, although logically they should be named in the following order: magmatic rocks, weathering of these, sediments, sedimentary rocks, weathering of these, soil formation-- But in that case, however, some topics would have to be dealt with twice, and in order to preclude that, we at once make a beginning with the sedimentary rocks themselves, as they are observed and become subject to weathering. Further on in this book, but perforce also here, their formation is mentioned.

From the beginning sedimentary rocks are to be differentiated along two lines: 1st according to size of the original particles, of which they are built up, into colluvium[4] and alluvium,[5] i.e., the so-called coarse granular and the fine granular sediments; and 2nd according to

4. The same word "colluvium" is used in the original. Dr. George B. Cressey calls to my attention that the current trend, at least in the United States, is to eliminate "colluvium" and to use "alluvium" for what our author separates into two groups.--Translator.

5. Regarding this see Chapter 4.

the chemical-mineralogical nature of the particles. Taken by and large, then one has to deal with only 4 sorts of material:

a. quartz--in the main present as sand in the coarse granular rocks;
b. clay--in the main to be found in the finely granular rocks;
c. lime--directly or indirectly of organic origin (especially in the marine sediments), to be found in coarser sediments as well as in the finer; as is also
d. detritus other than quarts and clay--in the Netherlands Indies especially of coarse and fine volcanic material.

In order to arrange the sediments graphically, one may place together two equilateral triangles as below in Fig. 3:

Inside of the triangles there may be placed the mixed sediments; for example:

x = a coarse coastal sediment { 50% quartz sand, 30% calcium carbonate, 20% volcanic sand }

y = a fine marine sediment, far from volcanoes { 80% clay, 20% calcium carbonate }

All river sands, free from CaCO, fall on the line a--b, all fine ashes falling into the sea and sinking there, fall on the line d--f, etc.

And when similar sediments have hardened to rocks, then the latter may also in a similar manner be arranged in a graph (see Fig. 4, page 12).

This scheme also is self-explanatory.

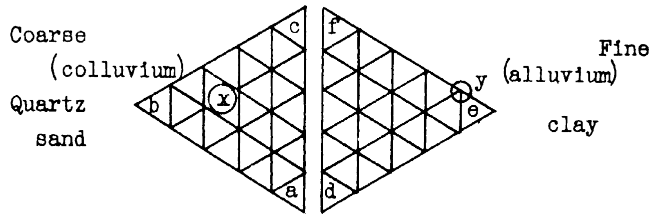

Fig. 3

Then it is possible for practical purposes to find in these triangles a place for all sediments.

For example,

segment (a) = coarse volcanic sand, gravel, or rocks.
" (b) = quartz sand and gravel.
" (c) = coarse limey sand and gravel, coral, or shells.
" (d) = fine volcanic sand and dust, in a word; ash.
" (e) = clay, which may or may not contain quartz powder.
" (f) = formanifera shells, for example, and other lime dust.

In judging as to how these sedimentary rocks behave with respect to weathering and soil formation, we may say that in a general way the constituents divide themselves into the four main groups lime, quartz sand, clay, and eruptive material.

* * * * *

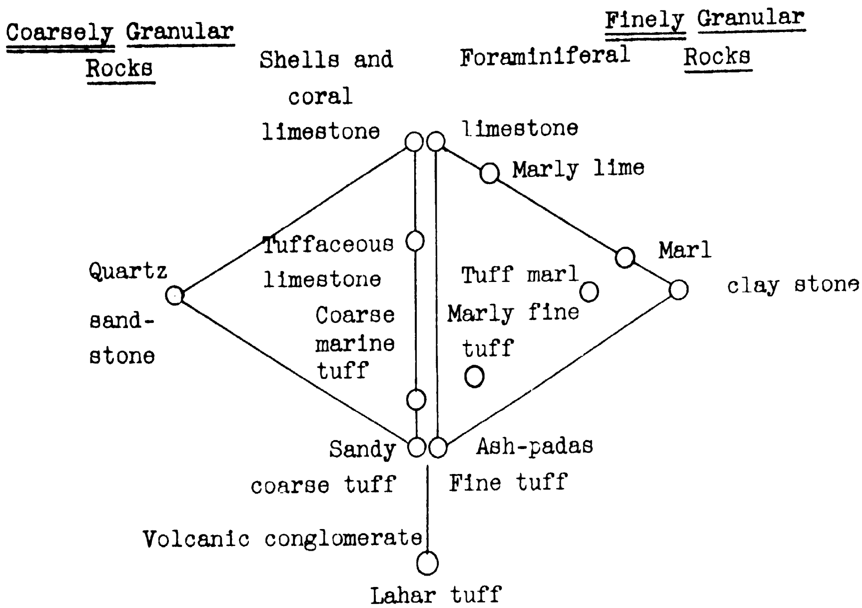

Fig. 4

In conclusion, something about the third group of rocks, which metamophose through alteration within themselves and which originate from rocks of the second, and in a few cases from those of the first group, the so-called metamorphic rocks. There are three conditions for such an origin:

1. heavy pressure, many times a so-called thrusting or a sliding pressure
2. an increase of temperature, and
3. a sufficiently long time.

A lack of one or even two of the conditions is frequently balanced or off-set by a greater intensity of the two others or of one of the two others. As a rule, the result is a recrystallization, wherein the minerals of the sedimentary rocks, as such, disappear, but at the same time new minerals crystallize from the constituents of the former minerals.

Although the above is a most inadequate statement we cannot here go into the phenomena as to how these came about; for a fuller statement the reader is referred to the works on petrography and petrogenesis.[6]

It may be sufficient to remark that with the metamorphosis, minerals originate which have already been named above (pp. 7-9), such as hornblende and various kinds of mica, but also others, such as garnet, epidote, tourmaline, chlorite, serpentine, etc. In so far as these are of importance for soil formation, we shall come back to them later.

A few of the most important metamorphic rocks occurring in the Netherlands Indies with their "parent material" may here be mentioned:

Quartzite, from quartz sandstone;
Marble, from limestone;
Hornstone, and with further crystal development: phyllite or slate, from claystone;
Garnet stone and eclogite from marls;
Mica slate and quartz mica slate from more mixed sedimentary rocks;
Chlorite, talc, and serpentine shales from material rich in magnesia, etc.

6. C. R. van Hise, Mon. U. S. Geol. Survey, 47 (1904); J. Johnston and P. Niggli, Journ. Geol., 21 (1913), p. 481 and 588; R. A. Daly, Bull. Geol. Soc. Amer., 28 (1917), p. 375; H. Grubenmann, Die kristallinen Schiefer (Berlin, 1904); U. Grubenmann and P. Niggli, Die Gesteinsmetamorfose (Berlin, 1924); H. E. Boeke and W. Eitel, Grundl. d. physik.-chem. Petrographie (Berlin, 1923).

For weathering and soil formation there arises only the question as to what the minerals now are, of which the metamorphic rocks consist; from what they have originated, is therefore relatively unimportant.

2. ACTUAL DATA

As the result of research in this field, almost all the rocks which are met with in the Netherlands Indies have been more or less accurately described petrographically; moreover, those descriptions have practically all been published. They deal with the characteristics of the minerals visible to the naked eye or under the magnifier, besides the enumeration of what minerals have been observed in thin sections under the microscope. Qualitatively and also quantitatively, it is stated which minerals predominate and which, on the other hand, have been observed only in small quantities: also, in which special form the minerals occur, and how the rock is built up and compounded out of them.

In the course of the last half century petrographic research has been continuously refined and one cannot but admire what able petrographers can say about rocks on the basis of these data. This however, applies principally to the qualitative, and only to a less degree to the quantitative. It is, for example, possible to describe an andesite with the utmost precision, and yet as to the question as to what the percentages of plagioclase augite, ore, and glass are, only a roughly approximate answer can be given. With reference to the feldspars, the matter is so far perfected that after an investigation as mentioned before a petrographer can rather accurately state the ratio of Na to Ca; but a substitution of, for example 1/5 of the Na by K can be "seen" much less sharply. Of the crystallography of augite and hornblende crystals a great deal can be seen, on the other hand but little regarding the chemical characteristics.

For soil science, however, the petrographic composition of the rocks is significant in the first place in so far as it gives light in answering the questions: How do the minerals and rocks weather to soil? Which weathering minerals originate in this process? and in what relationship are they to each other? Where and in which form do the different chemical elements of the rock go out or remain behind in the soil?

For example: sometimes all the phosphorus which is present is well crystallized out in the form of apatite. Say that it is 1 1/2% of the total, then the petrographer can easily discover its presence and describe it; another time twice as much phosphorus is present, but because it is dissolved in the volcanic glass and not crystallized, then this constituent, pedologically so important, will entirely escape the petrographer.

In short--the pedologist is thankful for the petrographic descriptions, yet he is by no means satisfied with them; he must also have at his disposal the chemical analyses of the rocks. Petrography, however, went further than the bare description. During its development from petrography to petrology it asked for more and more chemical in addition to mineralogical analyses.

In this way, little by little, a respectable number of chemical analyses of Netherlands Indies' rocks have been made; however, in comparison with the number of petrographic and mineralogical analyses this number is yet but very small.

It must be admitted that not all the analyses are of importance for our purposes. While from a geological standpoint perhaps the rocks occurring in "small lenses" or "basic concretions" or "thin veins" may be very important, they can here just as well remain outside of consideration, for we are concerned with soil-forming rocks.

Further, in the course of the last 50 years the methods of chemical analysis have been noticeably improved, refined, and extended; consequently in general, analyses made more recently deserve more confidence than those of earlier years: judged by the present-day available knowledge, unmistakable errors are evident in the earlier analyses.

However, not only errors of method are at issue, but also certain omissions in the determinations; in a number of older analyses the constituents P_2O_5 and TiO_2 were simply not separated and so were not

separately recorded; according to the course of the analysis the P and Ti were included with the Al_2O_3, so that the Al_2O_3 content was too high, thus erroneously stated. Also Mn, S, and Cl were frequently ignored in mentioning the constituents; furthermore Mg and Ca were often wrong. In brief, especially also with an eye to the requirements of the soil scientist of today, one could wish that many older analyses could be done over again. However, what is of value should be selected and here pieced together.

* * * * *

As to the analysis of the main minerals of the soil-forming rocks of the Netherlands Indies the situation is much more pitiful than for rocks in general; in the literature even now we find almost nothing about them. In the table below figures for certain minerals are collected which, though from the data of Clarke,[7] can give a rough idea of the chemical composition of these principal minerals. These are rounded off percentage figures showing approximately the limits of each constituent (see Table 1).

It is apparent how far apart the limits can be; and yet each horizontal line is limited to crystals which, crystallographically and optically, must be considered to belong to one mineral or one mineral group. That such a range is possible is to be ascribed to the possibilities of mutual substitution of different groups of chemical elements within the bonds of one crystal element (crystal molecule) or one crystal net.

Table 1

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	MnO	P_2O_5	F & Cl
Quartz	~ 100	---	---	---	---	---	---	---	---	---	---	---	---
Potassium feldspar	62-66	18-20	---	---	---	0-3	0-4	9-15	---	---	---	---	---
Plagioclase: Na-rich	61-70	19-26	---	---	---	0-9	6-11	0-4	---	---	---	---	---
Plagioclase: Ca-rich	50-60	27-35	---	---	---	10-20	0-5	0-2	---	---	---	---	---
Leucite	~ 55	~ 23	---	---	---	---	---	19-21	---	---	---	---	---
Mica: Muscovite	44-46	34-37	0-2	0-4	0-3	---	0-2	8-11	3-6	---	---	---	0-7
Mica: Biotite	33-36	13-30	3-17	5-17	2-20	0-2	---	6-9	3-11	1-3	0-2	---	0-3
Hornblende	38-58	0-19	0-6	0-22	2-26	0-15	1-3	0-2	---	0-2	0-2	---	---
Pyroxene: Augite	45-55	3-10	0-6	1-14	6-20	16-26	---	---	---	0-5	0-9	---	---
Pyroxene: Hypersthene	48-54	1-8	0-2	13-21	19-25	1-7	---	---	---	---	0-2	---	---
Olivine	35-43	---	0-3	5-34	27-51	---	---	---	---	---	---	---	---
Magnetite	---	---	~ 69	~ 31	---	---	---	---	---	---	---	---	---
Ilmenite	---	---	0-10	~ 50	---	---	---	---	---	~ 49	---	---	---
Apatite	---	---	---	---	---	~ 48	---	---	---	---	---	~ 40	~ 7
Glass: Acid, white	70-80	12-15	0-2	0-2	---	0-2	2-4	3-5	0-4	---	---	---	---
Glass: basic, black	46-60	14-20			0-2	2-3	2-6	3-4	0-2	---	0-2	---	---

7. F. W. Clarke, Analyses of Rocks and Minerals, U. S. A. Geol. Survey Bull., 419 (1910).

If we compare the above table with the contradistinctions on pp. 7-9, though it is true they cannot fully explain the mineralogical differences of rocks with high and low silica content, yet they make the differences much more plausible. And so it becomes comprehensible, why, in comparing the tables of rock analyses following with the above-given percentage compositions, the principal minerals are located as they are.

Whenever chemical weathering affects the minerals present, then it may be said that:

1st--each mineral begins to weather in its own way, independent of surrounding minerals, but depending upon the liquid surrounding this mineral: and

2nd--the constituents, either atoms or groups of atoms, once set free, then behave according to their chemical nature, and independent of the mineral from which they have been liberated. It is therefore obvious, that in a consideration of the weathering processes, one must pay attention not alone to the chemical elements, but at the same time to the mineral form in which these elements are exposed to weathering.

* * * * *

Of the magmatic rocks, the plutonic rocks have not been investigated nearly so much as the eruptive rocks. In Verbeek's book[8] of the west coast of Sumatra a number of plutonic rocks are found separated into "granitic rocks" and "rocks of the diabase group." Given the mineralogical composition according to the microscopic analyses, however, a number of the stated chemical compositions are impossible. Thus in Nos. 19, 54, 7, and 106 the figures for Al_2O_3 are certainly too high; in Nos. 54 and 105 the SiO_2 is probably too low; in No. 24 Al_2O_3 is too low in proportion to the amounts of the alkalies, etc. Consequently there remain[9] as acceptable (but therefore not yet admitted as accurate!) the analyses presented below in Table 2.

Table 2

ANALYSES OF PLUTONIC ROCKS OF SUMATRA

Name of the Rock........	Granitite	Syenite granite	Hornblende granite	Quartzdiorite containing augite	Quartz-diorite
Origin........	Koeantan	Boeloer Kasap	Between Gg Bessie and Bt. Bessie	Ahoer	Siloengkang
Analyzed by:..	Serrurier	Serrurier	Serrurier	Serrurier	Reuter
No.	4	44	68	66	105
SiO	73.24	67.66	62.84	61.36	55.10
Al_2O_3.........	12.87	15.39	15.29	15.38	16.19
Fe_2O_3.........	1.01	2.00	4.93	2.51	4.30
FeO	2.21	2.87	2.87	3.76	5.30
MgO	0.44	2.48	2.24	3.44	6.50
CaO	1.56	2.70	3.68	7.12	8.00
Na_2O	3.77	3.59	3.50	2.85	3.00
K_2O	4.48	2.66	3.22	2.72	1.49
H_2O (loss on ignition).	0.40	0.80	1.05	0.59	0.84
MnO	0.05	0.04	0.17	0.12	trace
P_2O_5	not det'd	not det'd	not det'd	present	1.01
TiO_2	not det'd	not det'd	not det'd	not det'd	present
Total	100.03	100.19	99.79	99.85	100.73

8. R. D. M. Verbeek, Topogr. en Geol. Beschr. v. Sumatra's Westkust (Batavia, 1883).
9. The first 4 of these 5 analyses were also copied by J. P. Iddings in his work: Igneous Rocks, Pt. 2; all others of plutonic rocks were not.

Note that the mineralogical composition changes with the chemical composition, there is a decreasing content of SiO_2 from No. 4 to No. 105. All 5 possess quartz, but No. 4 has the most; potassium feldspar is also present in all 5, but in large crystals in No. 4; on the contrary there is little calcium sodium feldspar (plagioclase) in No. 4, there is a little more in No. 44, and much more in No. 66 and in No. 105. All five rocks contain mica, but hornblende which is lacking in No. 4, is abundant in No. 44; also in the other three. Augite was observed only in No. 66; apatite in No. 66 and relatively much in No. 105. From the standpoint of practical soil science, it is very much to be lamented that phosphorus was not regularly determined; and therefore it is a matter for great rejoicing that it is being done at present, as is demonstrated by, among others, the considerable series of analyses published[10] not long ago by the Geological Survey at Bandoeng.

From this series we borrow a few more analyses of plutonic rocks, from west Borneo and the oldest part of Java (see Table 3).

Table 3

ANALYSIS OF PLUTONIC ROCKS OF BORNEO AND JAVA

Name of the rock........	Alkali granite	Granite aplite	Aplite granite	Granite	Theralite diabase	Diabase
Origin........	G. Tjempedak W. Borneo	S. Sokan W. Borneo	S. Poewan, weg Engkajoe-Semonbal W. Borneo	Nh. Belaban, Zijtak S. Sajan W. Borneo	Krg. Samboeng Lohoeloh region M. Java	Kg. Watoe Oerip Lohoeloh region M. Java
Analyzed by...	Willems	Willems	Willems	Willems	Esenwein	Den Haan
No.	1	22	23	24	25	26
SiO	76.36	77.53	74.72	69.49	54.61	47.90
Al_2O_3	10.57	12.42	13.66	15.34	15.58	14.75
Fe_2O_3	2.32	0.57	0.17	1.28	4.98	5.22
FeO	1.38	0.18	0.52	1.64	4.89	4.03
MgO...........	trace	0.01	0.18	1.17	3.26	7.12
CaO	0.20	0.19	0.82	3.26	5.08	7.37
Na_2O	4.29	3.75	3.40	4.29	5.94	3.98
K_2O	4.36	4.59	6.07	2.26	0.47	1.30
H_2O + ...	0.40	0.48	0.54	0.68	2.52	5.20
H_2O -	0.16	0.14	0.14	0.10	0.37	0.61
TiO_2	0.20	0.1-	0.14	0.32	2.15	2.30
P_2O_5	0.03	0.01	0.05	0.12	0.19	0.20
MnO	0.04	trace	0.01	0.06	0.20	0.13
CO_2		trace	trace	trace	0.17	trace
ZrO_2		00.02	trace			
BaO		---	0.04			
S						trace
	100.31	99.99	100.46	100.01	100.41	100.11

10. Jaarb. Mijnw., 59 (1930), Algem. Ged., "Petrochemie," p. 251-263.

These rock analyses demonstrate quite characteristically what was said on pp. 8 and 9 about more "acid" and more "basic" rocks. The four granites with a high silicic acid content are low in their iron, magnesium, and calcium; also low in titanium and phosphorus; the two samples of diabase, with a low silicic acid content are poor in potassium, but richer in iron, magnesium, calcium, manganese, titanium, and phosphorus; thus it is easy to understand that the mineralogical composition is also entirely different. It is true that of the last six rocks no mineralogical analyses were mentioned; but the names themselves already tell enough. Strong contrasts are, however, seen in the following plutonic rocks (see Table 4).

While in the first named rock there have been observed: quartz, othoclase, plagioclase, muscovite, and some amphibole and magnetite, the second is made up of olivine, enstatite, pyroxene and some chromite. It is apparent that the composition is entirely different, and as will appear further on, the weathering must thus also proceed entirely differently.

In order not to be too prolix, we shall not here discuss further a number of other plutonic rocks for the greater part coming from Timor[11] which have been analyzed mineralogically and chemically. If the reader be interested he can himself consult them in the literature mentioned. However, other than those mentioned above, there are found no further analyses of plutonic rocks from Java, Sumatra, Borneo and Celebes worthy of mention.

Much richer is the harvest of analyses of volcanic rocks.

* * * * *

Table 4

ANALYSES OF PLUTONIC ROCKS

Name of the rock.....	Aplitic micro-granite	Lherzolite
Origin...............	Bt. Kelam C. Borneo[1]	Eiland Moa[2]
Analyzed by..........	Dittrich	Morley
FeO	0.52	7.29
SiO_2	72.44	42.76
Al_2O_3	16.51	3.28
Fe_2O_3	0.24	0.97
MgO	0.05	40.67
CaO	2.47	1.53
Na_2O	4.54	0.21
K_2O	2.13	0.09
H_2O + ...	1.13	1.19
H_2O -	0.13	0.27
TiO_2	trace	0.06
MnO		0.24
P_2O_5		0.03
Misc.*...............		0.29
Total	100.16	99.88

* ZrO_2 - F-S-Cr_2O_3 -BaO-SrO-Ce_2O_3

1. J. Schmutzer, Miner. en chem. samenst. v. gest. v/h Müllergeb., verz. d. Molengraaff, Versl. K. A. v. W., W. en Nat. Afd., XVII (1908), p. 301-318.
2. H. A. Brouwer, Gest. v/h eil. Moa, Jb Mijnw. N. O. I., 45 (1916), Verh. I, p. 28.

11. Jb. Mijnw. N. O. I. 45 (1916), Verh. I, p. 13 and 69.

In a region like the Netherlands Indian Archipelago, the volcanic rocks play a much greater role than the plutonic rocks. For one thing, they occupy a far greater area; secondly, the land surface where these rocks are, for the reasons already above indicated, is more fertile, better suited to agriculture, thus much more thickly populated, and for that reason more easily accessible. It is no wonder that the volcanic regions have been more and more intensively investigated by financiers and that there are more analyses of the rocks. In accordance with what was said on pages 8 and 9, they will be dealt with by groups.

Volcanic rocks may be divided into three groups: the "acid" (with more than 65% SiO_2), the intermediate (with 52-65% SiO_2) and the "basic" (with less than 52% SiO_2), in general in a ratio (according to Niggli)[12] of about 30 to 42 to 28%. The volcanic rocks of the Netherlands Indies are more inclined to be basic; though the number of data is still insufficient for a proper estimate. They may be estimated very roughly to have a ratio from (10 to 20) to (50 to 60) to (30 to 40). One can safely say that the acid effusives and efflatas are relatively considerably less abundant, and where they do come to light, they have for the most part been violently ejected, so that there are found greater areas of tuff than of solid rock or lava.

* * * * *

In the Batak lands of North Sumatra acid effusives occur over great expanses. It is true that a large part occurs as tuff from ash and pumice (more about these later), but also as solid rocks. The following analyses (see Table 5) are found in the literature:

Table 5

ANALYSES OF ACID EFFUSIVE ROCKS OF NORTHERN SUMATRA

Name........	Liparite	Quartz trachite andesite	Quartz trachite andesite	Biotite dacite
Origin........	Lau Biang Bataklanden	Porobbo Toba Lake	Lau Renoen Pakpak Lands	Deleng Baros Batak Lands
Analyzed by...	Herz[1]	Herz[1]	Dittrich[2]	Herz[1]
SiO_2	71.25	69.44	67.75	66.71
Al_2O_3	14.21	15.21	15.51	15.82
Fe_2O_3	0.85	1.74	2.26	0.71
FeO	0.43	0.56	1.22	0.32
MgO	0.89	0.93	0.91	2.05
CaO	2.72	1.99	2.79	3.92
Na_2O	3.11	5.11	3.22	7.12
K_2O	6.74	4.53	3.15	2.42
H_2O + ...	0.48	0.77	2.29	1.01
TiO_2			0.32	
P_2O_5			trace	
Moisture......			0.45	
Total	100.68	100.28	99.87	100.08

1. L. Milch, Ueber Gest, v. d. Battakhochfläche., z. d. d. geol. Ges., 51 (1899), p. 62.
2. H. Stegmann, Die Jungen Ergussgest. d. Bataklânder, Sumatra, Inaug. Diss. Greifswald (Stuttgart, 1909); cf.: N. Jb. f. Min., Beil. Bd., 27, p. 436.

12. Referred to by F. Heide, in E. Blank's Handb. d. Bodenlehre, I, p. 116.

The small amount of iron and magnesium in these stones is striking; besides this the content of alkalies is high; yet but little sodium or calcium with it, and one can melt from it a relatively light-colored bottle glass.

It is to be regretted that the analyst Hertz had not also determined the phosphorus; that would have been very important from the pedologic standpoint.

Apart from a large content of colorless volcanic glass, all four of the rocks show the following mineral constituents: quartz, sanidine, plagioclase on the albite side, biotite, and a small quantity of amphibole, a few crystals of pyroxene and some magnetite.

* * * * *

No analyses yet exist of the acidic rocks, in the great tuff fields of the Plain of Agam (Sumatra's West Coast) and of the intermediate regions and uplands of Djambi. It is true there is one of liparite from south Palembang, apparently from the extensive tuff fields around the Ranau lake; this rock is very acid indeed, and agrees closely in composition with a few similar kinds from the Lampongs (see Table 6), which already are suspected to have been exposed to hydrothermal action.

Now before discussing Java and the link, Krakatau, which lies in between it and Sumatra, let us mention from other islands just a few analyses of rocks with more than 65% SiO_2 (see Table 7, page 20).

Four of these five rocks lie but just above the limit. Quite acid extrusive

Table 6

ANALYSIS OF ACIDIC EFFUSIVE ROCKS FROM SOUTHERN SUMATRA

Name..........	Liparite[1]	Liparite[2]	Liparite[1]	Silicified tuff	Silicified liparite Tuff[1]
Origin........	Kali Pajoeng S. Palembang	Mt. Koenjet Lampongs.	Mt. Kedaton Lampongs.	Kpg. Hoeroen W. K. Lampong-baai	K. Sebatoean Benkoelen.
Analyzed by...	Den Haan	Willems	Willems	Willems	Den Haan
SiO_2	72.52	74.54	73.99	75.48	67.66
Al_2O_3	12.94	14.39	15.22	13.65	11.64
Fe_2O_3	0.64	0.99	0.56	0.63	1.67
FeO	0.34	0.31	0.18	0.24	0.46
MgO	0.34	0.05	0.09	0.13	0.72
CaO	1.09	0.77	0.49	0.54	3.07
Na_2O	3.09	4.10	3.48	3.21	2.41
K_2O	5.14	3.56	3.49	3.87	2.60
H_2O + ...	3.25	1.03	1.79	1.10	8.23
H_2O -	0.62	0.37	0.86	1.14	0.84
CO_2	---	trace	trace	trace	---
TiO_2	0.19	0.14	0.15	0.09	0.47
P_2O_5	0.12	0.01	0.01	0.02	0.06
MnO	0.03	0.04	0.03	0.03	0.05
Total	100.31	100.30	100.33	100.11	99.88

1. Jb. Mijnw. N. O. I., 59 (1930), Alg. Ged., p. 257; Anal. Nr. 40 and 37.

2. Geol. Krt. Sumatra. Toel. Blad 1, pp. 19-20. --There this and the following rocks (No. 119 and 127) of the Sumatra Survey grouped with the "eruptive rocks of dacitic and liparatic composition." In the Jb. Mijnw. N. O. I., 59 (1930), Alg. Ged., p. 252-254 appear the same analyses however, with those of Kpg. Hoeroen under the Nos. 7-9 and 8 all three under the name "silicified tuff"; it is possible, regarding the composition, that the silification has not yet gone so far. In addition belongs here No. 7 originating from Gg. Boekit, Teloekbetoeng. Lpgs. --The petrological investigation of these rocks has not yet been completed, so that there may yet follow some light upon the matter. It is possible that the "silicified tuff" from Benkoelen will later receive another name.

Table 7

ANALYSES OF ROCKS HIGH IN SILICA FROM BORNEO, FLORES, AND TIMOR

Name............	Glassy[1] amphibole dacite	Amphibole[1] dacite rich in glass	Dacite[2]	Alkali Rhyolite[3]	Alkali trachyte[3]
Origin..........	Above Kebijan C. Borneo	Below Na. Pemali C. Borneo	Near the Manoe Bala River C. Flores	Between Atapoepoe and Soefa N. C. Timor	Between Toembaba and Haumeni N. C. Timor
Its own No.	II-710	II-599	XIII	III-288	II-320
Analyzed by.....	Dittrich	Dittrich	Tillmans	Morley	Pisani
SiO_2	66.16	65.72	65.48	70.76	65.10
Al_2O_3	15.39	15.06	14.37	10.16	14.10
Fe_2O_3	1.25	1.35	3.51	7.00	2.70
FeO	1.72	1.80	3.09	0.63	1.71
MgO	0.90	1.57	1.09	0.49	2.45
CaO	3.47	4.18	4.58	0.65	1.55
Na_2O	3.94	4.24	4.20	5.53	5.45
K_2O	2.00	1.07	0.72	2.57	4.92
H_2O + ...	4.94	3.77	1.73	0.88	2.10
H_2O -	---	0.69	---	0.57	
TiO_2	0.50	0.48	0.83	0.49	0.39
P_2O_5	not det'd	not det'd	not det'd	0.00	not det'd
	100.27	99.93	99.60	100.16*	100.47

* including 0.16 MnO, 0.12 BaO, 0.03 SrO, 0.06 S, 0.04 Cl and 0.02 F.

1. J. Schmutzer, Versl. K. A. v. Wet. Amst., Wis- en Nat. Afd., XVII (1909), p. 301-318.
2. G. Rack, Petrogr. Unters. an Gest. v. Soembawa u. Flores, N. Jb. f. Min. etc., Beil Bd., 34, p. 77.
3. H. A. Brouwer, Gest. v. Oost- Ned. -Timor., Jb. Mijnw., 45 (1916), Verh. I, p. 133.

rocks of other islands than Sumatra and Java thus are almost non-existent, at least in the analyses thus far carried out.

In the sample from Borneo apatite is stated to be a constituent; phosphorus, however, was not determined chemically. With the three others there is no indication of the occurrence of apatite; thus in general the rocks rich in silica seem to be quite poor in phosphorus.

Two forms of acid effusive rocks require special mention, viz. the obsidian which had flowed out, and the pumice which had been blasted out as foam.

Of obsidian from the Netherlands Indies, the following analyses are at our disposal (see Table 8, page 21).

There is much agreement among these analyses; little iron, almost no magnesium, little calcium, but much potassium, with an excess of silica. The single P_2O_5 determination indicates a high figure; we are unable to say what amounts the other three might show. It is too bad that the pumice, which was found along with obsidians, was not also analyzed; hence for pumice we are entirely dependent upon material from other sources.

With the exception of the Krakatau analyses (see p. 22), there is to be found but one analysis of pumice from the Netherlands Indies. As the fifth column this analysis has been added to Table 8 (page 21) of analyses of obsidian.

* * * * *

Table 8

ANALYSES OF ACIDIC EFFUSIVE ROCKS: OBSIDIAN AND PUMICE

Name..........	Obsidian[1]	Obsidian[2]	Obsidian[3]	Obsidian[3]	Pumice[4]
Origin........	Bongsoe-volcano K. Bras b. Djambak	Pilomasin S. Palembang	Djambi Sumatra	Tondano N. Celebes	Lau Matap Karo-lands
Own No........	279	39	1	---	VII
Analyzed by...	Krambers	Den Haan	Ledeboer	Ledeboer	Dittrich
SiO_2	78.15	75.52	72.26	74.87	68.81
Al_2O_3	11.94	12.32	13.44	12.88	14.61
Fe_2O_3	0.72	0.46	0.66	1.34	1.36
FeO	0.33	0.36	1.21	1.53	1.26
MgO	0.20	0.17	trace	0.15	0.74
CaO	1.32	0.95	1.34	1.44	2.21
Na_2O	0.67	2.97	3.05	3.29	3.31
K_2O	5.71	6.51	4.05	4.16	4.61
H_2O	0.14	0.34	0.80	0.29	2.92
MnO	1.58	0.02	not det'd	not det'd	not det'd
TiO_2	not det'd	0.21	0.20	0.27	0.36
P_2O_5	not det'd	0.37	not det'd	not det'd	trace
Total	100.76	100.20	100.01	100.22	100.19

1. R. D. M. Verbeek, Sum. Westkust, p. 415 en 517.
2. Jb. Mijnw., 59 (1930), Alg. Ged., p. 257; Anal. Nr. 39.
3. Iddings, Ing. Rocks (1913), II.
4. Stegmann, l. c., p. 438.

While it may be perfectly correct, as Verbeek says, that "glass-like products, peckstone, obsidian, and pumice, with reference to the rocks with a 'rocklike' (apparently the meaning here is the rock rich in crystals) ground mass appear in Java to be of minor importance,"--yet it strikes one that except for the analyses by P. J. Maier[13] so very little attention has been paid to the acid rocks of Java; in vain one searches for modern analyses which give, among other things, P_2O_5. The figures of Maier are given in Table 9.

Although the total exceeds 100%, yet there are still lacking H_2O, Cl, etc. which cannot be concealed in the other amounts, while TiO_2, P_2O_5, etc., can be. Hence analyses like these have only a very approximate value.

Table 9

Analyses of Acid Rocks of Java

	No. I (p. 305)	No. II (p. 307)
SiO_2 ...	79.00	80.80
Al_2O_3 ...	13.08	9.85
Fe_2O_3 ...	2.27	3.33
CaO ...	1.08	0.85
MgO ...	0.30	0.21
Na_2O ...	3.26	3.49
K_2O ...	3.72	3.83
Total ...	102.71	101.36

13. Nat. Tschr. N. I., VI (1854), p. 301-310, referred to in: Verbeek & Fennema: Geol. Beschr. v. Java en Mad. (1896), p. 703.

Analyses are lacking of the other occurrences in Java of obsidian, or pumice, or white and acid tuffs. However, if we stop to think of the enormous areas occupied by the "white tuffs" of Bantam, and the "acid tuffs" of Soerakarta, Madioen, and still other occurrences, then a few analyses, if only for orientation as to their content of P_2O_5, K, and Ca, could certainly not be considered superfluous.

* * * * *

No spot in Java has been so intensively studied as the islands of Krakatau. It might seem that in such a work as this a consideration of analyses of Krakatau rocks would be out of place--yet from those researches data appear which have a more general application than to this volcano alone. This will appear presently.

Krakatau is an active volcano, which by turns erupts acid, intermediate, and basic rocks.

Analyses of some acid rocks are given in Table 10.

Comparing these analyses with each other shows that the differences are small; even when comparing the more compact peckstone and the foamy pumice; except that the latter contain 2% H_2O, which is lacking in the peckstones. Genuine obsidians are not included here; yet there occur pieces of pumice, which without a sharp boundary gradually go over into compact "glass"; but therewith the K content does not increase to amounts above the Na content, or even above the (Na_2O + MgO + CaO) content,

Table 10

ANALYSES OF SOME ACIDIC ROCKS FROM KRAKATAU

Name..........	Andesitic peckstone[1]	Peckstone[2]	Tridymitic[2] andesite	Tridymitic[2] andesite	Peckstone[2]	Andesitic[1] pumice stone	Dark andesitic[1] pumice stone	Pumice[1] stone
Origin........	Lang Eiland	Rakata	Rakata	Rakata	Lang Eiland	Lang Eiland	Lang Eiland	Lang Eiland
Own No........	2283	87	2298	86	83	2317	2083	82
Analyzed by...	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber
SiO_2	71.50	70.62	70.43	70.18	68.69	67.64	66.38	66.32
Al_2O_3	14.48	12.77	15.21	13.92	13.54	14.54	16.94	13.93
Fe_2O_3	1.00	1.82	1.96	2.41	1.28	2.26	1.35	1.61
FeO	1.58	2.48	1.76	1.79	2.44	1.89	2.65	2.15
MnO	0.08	0.07	0.05	0.06	0.11	0.06	0.08	0.10
MgO	1.02	0.74	0.64	0.78	1.28	0.99	1.14	1.18
CaO	2.56	2.83	2.54	2.66	3.45	3.02	3.11	3.52
Na_2O	4.21	5.48	3.92	4.85	5.69	4.03	4.09	5.17
K_2O	2.89	2.24	3.08	2.25	2.22	2.91	1.78	2.10
H_2O + ...	0.035	0.05	0.15	0.10	0.27	2.06	2.12	2.13
H_2O -	afw.	afw.	0.04	0.12	0.04	0.08	0.30	0.11
TiO_2	0.60	0.16	0.42	1.09	1.09	0.57	0.64	1.40
P_2O_5	trace	0.08	trace	0.04	0.26	0.06	afw.	0.08
Cl	0.08	trace	afw.	trace	trace	afw.	0.25	0.24
SO_3	0.03	trace	afw.	trace	afw.	0.13	trace	0.30
Total	100.065	100.34	100.20	100.25	100.36	100.24	100.83	100.34

1. Ch. E. Stehn "Krakatau", IVth Pac. Sci. Congr., (Bandoeng, 1929), p. 53.
2. Jb. Mijnw. Ned.-Indië, Alg. Ged., 59 (1930), p. 261.

as is many times the case with true obsidians. Meanwhile, we know that the "glass" of Krakatau when heated above 800° C rises like bread and is transformed into pumice; the difference between the first five and the last three rocks of the above table is perhaps nothing more than a question of temperature; the latter have had an opportunity above 800°C, to get rid of their gas (especially NH_4Cl), but the former have not; it may even be that they had no occluded gas. This is not apparent from the analyses; perhaps through special search for it in the rocks that have not been "raised," a certain content of NH_4 can be established.

Apart from this it should be pointed out that all the "acid," that is silicic acid-rich, rocks possess relatively little iron and very little magnesium; also the phosphorus content is very small, with a single exception, where it is moderate.

* * * * *

Before proceeding to a consideration of the so-called neutral or basic rocks, let us first review a few things of one sort or another from the notable research on the Krakatau eruptives by Verbeek in his exhaustive monograph on Krakatau.[14] Verbeek has not limited himself entirely to a mineralogical description on the one hand and a total chemical analysis on the other hand, but in cooperation with J. W. Retgers he has, as far as possible, broken up the rocks into the minerals which compose them and then had those minerals analyzed separately. Especially pumice and even more so volcanic ash lend themselves to this treatment, and--it may be mentioned in passing that few other researchers have done this, either before or after him.

With the help of liquids of different specific gravity a quantity of Krakatau ash was divided up into the following fractions:[15]

Pumice	69.8%	
Heavy glass particles	21.1%	
Feldspars	6.0%	
Magnetite	0.9%	
Pyroxene	2.2%	(Hypersthene..1.36% (Augite.......[illegible].64%
	100.0%	

The notable thing about some of this Krakatau ash which was collected at Buitenzorg is that it consists of 91% glass and only 9% crystals.

Another fine ash, collected from the uppermost layer on the island of Sebesie, and thus apparently the last which had fallen, contained but 1.5% crystals of which 1.3% was feldspar, and 0.2% heavy minerals. The ratio 7:1 is entirely different than in the (mixed) Buitenzorg sample, which had a ratio of 2:1. Verbeek already points out also directly, that <u>in the ash both according to the place of collection and according to the time in the eruption</u> (beginning, middle, end, etc.) <u>a great difference can occur with reference to the mineralogical composition of the whole</u>, that is, the glass + the crystals. But then <u>these wide variations occur in the chemical composition</u> of the rock as a whole, for the mineralogical components diverge strongly in their chemical composition.

Verbeek and Retgers in the first place very accurately separated the <u>feldspar crystals</u> from the ash and divided them according to their specific weight into twenty-one groups. By doing so there was the possibility of calculating the content of calcium feldspar or anorthite, sodium feldspar or albite, and potassium feldspar or sanidine, and from these data calculating the probable chemical composition of the complete mixture of the twenty-one groups.[16]

SiO_2	57.87%
Al_2O_3	26.59%
CaO	8.19%
Na_2O	6.13%
K_2O	(1.22)%
	100.00 %

14. R. D. M. Verbeek, Krakatau (Batavia, 1885).
15. L. c., p. 205.
16. L. c., p. 247.

A second, somewhat less exact separation of a fresh quantity of feldspar crystals into only fourteen groups gave, after conversion, these figures:--

SiO_2	58.01%
Al_2O_3	26.49%
CaO	8.07%
Na_2O	6.21%
K_2O	(1.22)%
	100.00%

Only the potassium content was obtained from a direct chemical analysis, which resulted in these figures:

SiO_2	58.29%
Al_2O_3	27.19%
CaO	8.27%
Na_2O	5.82%
K_2O	1.22%
	100.79%

If one now compares the results, taking into consideration the fact that the chemical method of analysis obviously must give somewhat too high SiO_2 and Al_2O_3 figures, then the agreement is indeed very satisfactory.

In the same way the Thoulet solution was used to separate the pyroxenes from the rest, and thereafter the hypersthene crystals were most meticulously picked out. The same was done with the augites. The following figures (Table 11) show the chemical composition:[17]

Table 11

ANALYSES OF HYPERSTHENE AND AUGITE SEPARATED FROM KRAKATAU ASH

	Hypersthene	Augite
SiO_2	52.3%	48.6%
TiO_2	trace	trace
Al_2O_3	6.1%	8.2%
FeO	27.7%	14.0%
MnO	trace	trace
MgO	13.6%	11.6%
CaO	2.2%	18.9%
Total	101.9%	101.3%

17. l. c., p. 264 and 273.

Although these analyses are most probably not entirely accurate, (for the titanium might have been determined more completely, certainly some Fe_2O_3 was included in the FeO and neither the Na_2O nor the P_2O_5 were determined), yet with the exception of the FeO of the hypersthene there is presented quite a good picture of the composition which falls entirely within the limits given on page 14.

In addition, the chemical analysis of the magnetic iron ore shows a composition of:

81.6% Fe_3O_4 (Magnetite)

18.4% Fe_2TiO_4 (Ilmenite)

in addition a small quantity of hexagonally crystallized ilmenite was also found, as well as some apatite and a few still less important minerals, too few to analyze.

Finally, the volcanic glass was analyzed, and this gave the following figures:

SiO_2	68.12%
TiO_2	0.18%
Al_2O_3	15.81%
Fe_2O_3	5.01%
FeO	(in Fe_2O_3)
MgO	1.18%
CaO	2.78%
Na_2O	5.09%
K_2O	1.06%
	99.23%

If now these figures are multiplied by the percentage in which the glass occurs in the total ash, and the same is done for feldspar, hypersthene, augite, and ore, then the total must equal the total ash. Thus Verbeek arrived at a total which is given in column 8b of Table 12 (page 25); while an analysis by C. Winkler, converted to the same constituents, is shown in column 8a.

Even though there may be all kinds of gaps and even errors in these analyses, yet they give an insight into the principal constituents of a typical volcanic ash, such as that which fell at Buitenzorg on August 27, 1883. We only wish that other rocks also had been investigated in this manner; such a method would certainly give

Table 12

ANALYSES OF VOLCANIC GLASS AND CALCULATED PERCENTAGES OF COMPONENTS

	Volcanic glass	Feldspar	Hypersthene	Augite	Magnetite	Total (8b)	Analyzed by C. Winkler (8a)
SiO_2........	61.99	3.50	0.71	0.31	---	66.51	66.77
TiO_2........	0.16		trace	trace	0.07	0.23	0.67
Al_2O_3.......	14.39	1.63	0.08	0.05	---	16.15	16.44
Fe_2O_3.......	2.96				0.64	3.60	3.41
FeO.........	1.44	---	0.38	0.09	0.29	2.20	1.37
MnO.........		---	trace	trace	---	trace	0.38
MgO.........	1.07	---	0.18	0.07	---	1.32	1.67
CaO.........	2.53	0.50	0.03	0.12	---	3.18	2.90
Na_2O........	4.63	0.35	---		---	4.98	4.14
K_2O.........	0.96	0.07	---	---	---	1.03	2.25
Total.......	90.13	6.05	1.38	0.64	1.00	99.20	100.--

a very much better insight than merely total analyses.

However, with an eye to the usefulness of the analyses in soil science, the phosphorus should certainly also always be regularly determined at the same time. But in addition to P there are also other elements, which in small quantities play an important role biologically: Mn, S, Cl, F come under this head and are no longer disregarded in modern analyses. But in addition Cu, Bo, and Mo also appear to be of considerable significance which is not to be underestimated; perhaps there are yet still other important elements as for example Va, but we do not yet know about them. In short, considered from the biological point of view, an analysis of rock, as a parent material of the soil, can never be complete enough. If then at the same time we know in which minerals the different elements are especially accumulated, then important biological data can result.

* * * * *

From the additional analyses recorded by Verbeek these following are selected. Firstly three analyses from Winkler (see Tables 13 and 14):

Table 13

ANALYSES OF VOLCANIC ASH AND PUMICE FROM KRAKATAU

	No. 7	No. 8	No. 9
SiO_2............	60.13	66.26	68.51
TiO_2............	1.10	0.66	0.82
Al_2O_3...........	17.41	16.31	15.96
Fe_2O_3...........	4.30	3.38	2.61
FeO.............	1.68	1.36	1.09
MnO.............	0.40	0.38	0.28
MgO.............	2.27	1.66	1.07
CaO.............	3.36	2.88	3.14
Na_2O............	4.88	4.11	4.01
K_2O.............	2.46	2.23	1.82
$CaSO_4$ (anhydrite)	1.57	0.62	---
Organic matter (carbon)	trace	trace	---
Insoluble in H_2O	99.56	99.85	99.31

No. 7 is ash, collected before the great eruption on August 11 on (the later submerged) island Perboewatan, within the great ring crater. No. 8 is the ash already mentioned above, collected on the 27th of August at Buitenzorg. No. 9 is light colored pumice stone, gathered by Verbeek on Krakatau on the 16th October following.

Table 14

ANALYSES OF VOLCANIC ASH AND PUMICE FROM KRAKATAU

	No. 7	No. 8	No. 9
Insoluble in H_2O	99.56	99.85	99.31
NaCl.............	0.75	0.65	1.09
KCl..............	trace	trace	trace
Na_2SO_4...........	0.22	0.02	---
$CaSO_4$............	0.11	0.21	0.22
$FeSO_4$............	0.03	0.01	0.03
Total............	100.67	100.74	100.65

We can clearly see the differences between a more basic ash and one entirely acid: from No. 7 to 9 the SiO_2 increases, but iron and magnesia, that is, the constituents of the dark minerals decrease.

* * * * *

As to the silicic acid content, the following figures (see Table 15) were determined (calculated upon the water free basis):

All these figures closely approach those of the pumice stone No. 9 yet they also lie lower than the true obsidian, recorded above (see Table 8).

Three more analyses have been published of the ash which fell in Batavia in 1883. From those by Van Der Burg[18] we must mention here particularly the P_2O_5 content of 0.15%; none of the other investigators paid any attention to the phosphorus. The content (if indeed this is all there is of it) is about average, certainly not high.

Then Van der Burg found that of this fresh ash 8.42% was soluble in hydrochloric acid. This demonstrates what a mistake it is to consider that only that part of a sample of partially weathered rock which is insoluble in HCl is "unweathered." To be weathered, and to be soluble in acid, are two different things which have nothing to do with each other.

The analysis by Renard[19] shows that there is little difference between the ash which fell at Batavia and at Buitenzorg; he recorded a TiO_2 content of 0.62% which approaches that of Winkler's No. 8.

According to the criticism of Verbeek,[20] the analyses by Sauer[21] are not of sufficient value to be mentioned here. On the other hand an analysis by Schwager[22] is however worthy of record, in that he

Table 15

SILICA CONTENT OF GLASSY ROCKS FROM KRAKATAU

	SiO_2	Analysis from
No. 2 Glass rock from the Poolschen Hoed	68.75	J. W. Retgers
No. 3 Glass rock from the Poolschen Hoed	69.89	K. H. Mertens
No. 4 Glass rock from the Poolschen Hoed	70.01	K. H. Mertens
No. 5 Glass rock from the Poolschen Hoed	70.48	K. H. Mertens
No. 15 Piece of glassy obsidian with a crust of pumice (1883); only the glass............................	68.27	Cretier

18. Rec. d. trav. chim. (Pays-Bas, 1883), p. 298-303.
19. Bull. Acad. Roy. Belgigue, 3e Ser. VI (Séance 3 Nov. 1883).
20. Ber. d. naturf. Ges. (Leipzig, 1883), pp. 308-310 (Ref. Chem. C. bl. 1884, pp. 129-133).
21. L. c., p. 87.
22. In: K. Oebbeke, Ueber die Krakatau-Asche. N. Jb. f. Min. 1884, II, p. 32-33.

was dealing with an ash collected August 28, 1883 on a ship 1441 Km. from the volcano. We would thus expect that the "heavy" elements would have already been noticeably sorted out, and indeed it does appear that the Fe_2O_3 content was greatly reduced, that is, to only 0.28%. The heavier magnetic iron ore had thus already fallen into the sea before the ash got as far as the ship.

* * * * *

In addition to the acid kinds of ash mentioned here, Krakatau has also produced basic ash; of these we find the following analyses (see Table 16).[23]

In the two analyses of basaltic lava, placed alongside of the others in the right hand columns one sees how close together in all the main constituents the composition of the ash and lava agree. It is all the more remarkable that the lavas and the two youngest ashes have a phosphorus content of approximately 0.25 percent, while the two somewhat older ashes practically none; it is not possible for me to explain this. One might call it an accident and perhaps the close agreement in the other constituents is also an accident. This is a very weak argument; I hope the phenomenon mentioned here may be a stimulus to much more accurate P_2O_5 determinations: so as to enhance the chance to be able to say something more general as to the occurrence of the phosphorus, which for soil science

Table 16

ANALYSES OF BASIC VOLCANIC EJECTA FROM KRAKATAU

	Basaltic ash		Ash of 26-6-'30	Ash of 1930	Basaltic lava	
Origin..........	Perboewatan	Lang Eiland N. W. Jan. 1928	Krakatau	Krakatau	Zwarte Hoek oldest layer	Rakata Uppermost Layer
Own No.	8231 SK	2088	70	41	2081	2289
Analyzed by.....	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber
SiO_2	51.04	51.81	52.92	52.85	50.25	53.63
Al_2O_3	19.77	18.48	16.84	17.03	18.16	18.01
Fe_2O_3	4.80	2.95	2.57	2.20	3.36	4.03
FeO	5.10	6.64	6.54	6.98	8.52	6.09
MnO	0.18	0.21	0.13	0.12	0.17	0.08
MgO	4.00	5.97	5.39	5.25	5.25	4.37
CaO	9.43	9.05	8.74	8.36	9.32	8.13
Na_2O	2.89	2.97	3.35	3.69	2.46	3.05
K_2O	1.37	1.07	0.82	0.85	1.02	1.06
TiO_2	1.05	0.93	1.42	1.49	1.28	1.20
Cl		0.003	0.31	not det'd		trace
SO_3	0.15	0.05	0.10	not det'd		trace
P_2O_5	trace		0.35	0.25	0.28	0.19
H_2O + ...	0.20	0.14	0.27	0.83	0.28	0.23
H_2O -	0.02		0.48	0.39		
Total	100.00	100.273	100.23	100.29	100.35	100.07

23. "Krakatau", IVth Pac. Sci. Congress, (Bandoeng, 1929), p. 53.

is of so much significance.

Now let us snatch just a few data from the available analyses[24] of more recent date, demonstrating that not only the two most extreme groups of basic and acid rocks were thrown out by the Krakatau volcano, but also there were erupted the intervening links of less basic and more of so-called neutral nature (see Table 17):

Table 17

ANALYSES OF INTERMEDIATE VOLCANIC PRODUCTS FROM KRAKATAU

Name............	Basalt	Basalt lava	Olivine basalt	Basalt	Andesite	Andesite
Origin..........	Rakata, Krak.	Rakata, Krak.	Zwarte Hoek. Kr.	Rakata, Krakatau	Krakatau	Krakatau
Own No.	68	69	42	71	73	78
Analyzed by.....	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber
SiO_2	48.54	48.82	48.95	53.96	57.86	60.82
Al_2O_3	14.98	18.16	16.82	16.10	13.95	13.34
Fe_2O_3	4.40	5.04	4.41	3.47	4.32	4.02
FeO	6.25	4.45	6.14	6.58	4.74	3.30
MnO	0.15	0.11	0.04	0.15	0.12	0.11
MgO	6.97	4.72	5.48	4.52	3.94	3.04
CaO	10.76	12.75	9.52	8.57	7.44	6.47
Na_2O	2.94	2.91	2.46	3.38	4.21	4.68
K_2O	0.34	0.32	0.47	1.05	1.29	1.37
TiO_2	1.65	1.23	1.76	1.97	1.10	1.40
Cl	not det'd	not det'd	not det'd	trace	not det'd	trace
SO_3	trace	trace		not det'd	not det'd	not det'd
P_2O_5	0.24	0.22	0.22	0.17	0.34	0.35
H_2O + ...	1.32	0.61	1.73	0.36	0.56	0.58
H_2O -	1.78	0.90	1.96	0.12	0.40	0.80
	100.32	100.24	99.96	100.40	100.27	100.28

basic materials contain more crystalline material. It is very worth while to investigate a basaltic ash, as referred to above under No. 8231 SK, just as Verbeek did with the acid ash No. 8, in order to trace whether the expectation is correct that the glass content is significantly lower than 90%; the feldspar more; augite, hypersthene and ore likewise more; and

Taken together from what here has been stated regarding the products of the Krakatau, one can say that a volcano such as this produces eruptives of very divergent nature and composition, one time very acid, then very basic, then again intermediate. The acid eruptives possess much glass, sometimes consisting largely or almost entirely of it. As a whole the also if amphibole and olivine are found in the ash. If, finally, both the feldspar and the dark minerals are analyzed by themselves and the results compared with those of the mineral analyses from Verbeek's investigation, it should be apparent as to what differences one must especially look for: (1) differences in the proportions of the minerals while the minerals exhibit

24. Jb. Mijnw. Ned.-Indië, 59 (1930), Alg. Ged., p. 261.

only small variations; (2) differences in the magma, as a result of which, right from the beginning the minerals themselves were different; or (3) differences in the rocks because of both the reasons cited.

In his summing up of the chemical results, Verbeek[25] takes the position that only two groups of rocks of Krakatau should actually be considered, namely hypersthene andesites, etc., with a silica content of between 66.5 and 70%, and basalts with an average of 49% SiO_2. Apparently Verbeek did not have at hand samples of the above-mentioned andesites of 54-60% SiO_2, or, if so, he did not analyze them.

By way of exception, he recorded "a solitary kind of ash" of 61% SiO_2. The most recent work of the Volcanological Service has now filled in this hiatus.

Under 4° Verbeek says: "The pure pumice stone glass contains approximately 69% SiO_2; the farther from Krakatau the ash fell, the poorer it was in crystals, and the closer the composition of the ash approached that of the pumice stone with 69% SiO_2." Therein lies the idea that the glass is of similar composition, consequently the composition of the glass-containing rocks depends upon the greater or less admixture of diverse crystals in the glass. For one eruption this idea is certainly logical and acceptable; J. Th. White[26] and I accepted the idea and we worked it out for the Kloet ash of 1919 (more about this further on). But can one then say in general that the composition of glass from different eruptions varies only within very narrow limits? By no means. For this reason the analysis of th the glass of the so-called "basaltic ashes" is so very desirable.

From the standpoint of soil science it is without doubt interesting to know where the potassium is: in the feldspars or in the glass, and as for the former, whether in the large phenocrysts as well as in the fine feldspar powder and ground-mass. Although since 1883 the optical investigation of the feldspars has been notably refined, it still seems desirable to supplement this by analyses of glass and phenocrysts.

With respect also to the phosphorus there still remain unanswered a few questions: where does it accumulate? in the first crystals, therefore, as the very first generation (apatite), serving as crystal nuclei? or does a good deal of it remain dissolved in the glass? Only many analyses can throw light upon these questions. From the available analytical data nothing is to be found which will throw light upon these points.

* * * * *

Following the extended discussion of the eruptive rocks of Krakatau, as examples of the group, we may be more brief in our treatment of the neutral basic eruptive rocks of the other volcanoes in the Netherlands Indies.

The following analyses (see Table 18, page 30) relate to rocks of the intermediate sort from the Batak lands (Sumatra).[27]

The mineralogical composition agrees beautifully with the analyses: quartz occurs only in V and II, when the SiO_2 is greater than 58%; potassium feldspar (sanidine) was clearly seen microscopically only in II (highest potash figure); biotite, much in V, less in II, goes together with the most combined water. From the left toward the right iron and magnesium increase strongly, calcium also, but less; and in connection with these the content of the dark minerals is as follows:

V	Mica	Hornblende			(Magnetite)
II	Mica	Hornblende	(Augite)		Magnetite
XI		Hornblende	Augite	(Hypersthene)	Magnetite
XII		Hornblende	Augite	Hypersthene	Magnetite
I			Augite	Hypersthene	Magnetite
II			Augite	Hypersthene	Magnetite

25. L. c., p. 312.
26. Versl. le Bijeenk. Ver. v. Proefst. Pers., (Bzg., 1919), p. 75-99.
27. H. Stegmann, Inaug. Diss., (Greifswald 1909), N. Jb. f. Min. Beil. Bd. XXVII, p. 401-459.

Table 18

ANALYSES OF INTERMEDIATE VOLCANIC PRODUCTS FROM THE BATAK LANDS OF SUMATRA

Name	Biotite Hornblende dacite	Quartz-trachyte andesite	Hornblende pyroxene andesite	Pyroxene andesite lava flow	Pyroxene andesite	Hyperathene andesite
Origin	D. Palpaian Karolands	Boeloe Nipis	Top of the Sinaboeng Karol.	Sinaboeng near Soekanaloe	above Parsambilan Toba lake	Mt. Sing-galang Toba Timoer
Own No.	V	II	XI	XII	I	III
Analysis from	Dittrich	Dittrich	Dittrich	Dittrich	Dittrich	Dittrich
SiO_2	62.23	60.78	57.70	55.99	55.18	53.94
Al_2O_3	16.96	17.63	16.36	18.19	18.02	18.93
Fe_2O_3	1.27	3.82	4.20	4.10	3.29	4.06
FeO	2.92	2.18	3.47	3.85	4.94	5.08
MgO	2.02	2.25	3.41	3.02	3.81	3.23
CaO	6.56	5.75	7.32	8.27	7.51	7.85
Na_2O	3.07	2.86	3.22	3.28	2.60	2.56
K_2O	1.07	2.56	2.11	1.53	1.89	1.68
H_2O +	2.47	1.38	1.14	0.99	1.09	0.92
H_2O -	0.81	0.24	0.16	0.20	0.58	0.42
TiO_2	0.63	0.62	0.71	0.70	0.96	1.06
P_2O_5	trace	0.06	0.14	0.13	trace	trace
S				trace	trace	
CO_2	0.10				0.10	
Total	100.11	100.13	99.94	100.25	99.97	99.73

The content of titanium also increases from the left toward the right; the phosphorus, however, is everywhere in very small to extremely small amounts, without any regularity.

Additional analyses of similar Sumatran rocks, recorded in the literature already referred to, offer no new viewpoint. Schmutzer[28] records an analysis by Dittrich of a biotite amphibole-andesite, collected under No. II 749 by Molengraaff near Tebaoeng opposite Na. Oeroei in Central Borneo. This rock has a composition very closely agreeing with No. V of the above considered Batak rocks. Although apatite was recorded as a mineral by Schmutzer, P_2O_5 does not appear in the analysis.

* * * * *

From Java thousands of rock samples have been determined mineralogically and in part minutely described; it is notable however, that only a few tens of chemical analyses have been performed and published, for the greater part in recent times, and for the rest limited to specimens from but a few parts of Java. Above in Table 9, p. 21, were quoted a couple of analyses of obsidian coming from the Kawah Manoek volcano; they are apparently the only rock analyses which were available to Verbeek and Fennema for their Geological Description of Java and Madoera.

Now there have been added[29] analyses of rocks of the Tengger mountains, Mt. Slamat, and Mt. Goentoer. According to the descriptions in the handbook of Verbeek and Fennema these rocks are all basalts. If

28. L. c., Versl. K. A. v. W., W. e. Nat. Afd., XVII (1908), p. 315.
29. See the already more cited series of analyses in: Jb. Mijnw. N. O. I. 1930, Alg. Ged., p. 252-263.

Table 19

Analyses of Volcanic Rocks of Java: Basalts and Related Sorts

Name...........	Basalt	Glassy Shoshonite	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
Origin..........	Goentoer	Bromo-crater	Waterv. Sirawani Tengger Mts.	Kali Besi Tengger Mts.	G. Penandjahan Tengger Mts.	Waterv. Sirawani Tengger Mts.	G. Poendak Lemboe Tengger Mts.	Moenggal slope Tengger Mts.	Klip in Sand Sea Tengger Mts.
Own No..........	(10)	(9)	(18)	(15)	(20)	(14)	(17)	(19)	(16)
Analysis from...	Morley	Morley	Patoir	Patoir	Patoir	Willems	Patoir	Patoir	Patoir
SiO_2	51.12	55.42	49.45	50.75	51.07	51.46	54.02	59.01	59.13
Al_2O_3	19.59	17.39	19.03	17.97	18.15	15.33	18.68	17.04	14.76
Fe_2O_3	2.86	1.56	3.76	4.40	3.81	6.10	3.13	2.79	2.24
FeO	6.53	6.82	6.07	7.43	7.48	7.11	5.34	4.72	6.48
MgO	4.47	3.28	6.83	4.21	4.68	4.54	2.34	1.54	1.58
CaO	9.54	7.57	10.00	8.64	8.07	8.44	7.68	4.40	5.06
Na_2O	3.11	2.41	2.98	2.56	3.28	2.76	3.40	4.31	3.80
K_2O	0.57	2.67	0.44	1.75	0.93	1.61	1.34	3.06	3.62
H_2O + ...	0.11	0.17	0.46	0.67	0.89	0.43	1.62	0.70	0.49
H_2O -	0.10	0.06	0.34	0.24	0.66	0.46	0.91	0.83	0.22
TiO_2	0.86	1.07	0.92	1.47	1.29	1.45	1.13	1.23	1.05
P_2O_5	0.14	0.58	0.14	0.30	0.30	0.28	0.29	0.60	1.59
Cl	0.10	0.11	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd
MnO	0.65	0.71	0.11	0.18	0.06	0.17	0.09	0.09	0.13
BaO	0.03	0.13	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd
SrO	0.03	0.03	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd
Total	99.81	99.98	100.53	100.56	100.58	100.14	99.97	100.32	100.15

that were correct the range of the chemical composition ought to be rather limited; this does not, however, appear to be the case; from the thirty-one analyses available (Geontoer 1, Tengger 8, Slamat 22) we select those in Table 19.

* * * * *

To call Nos. 18, 15, 20, and 14 basalts is quite acceptable, but for basalt Nos. 19 and 16 have a composition somewhat too widely divergent. After being more closely examined microscopically these rocks ought to be given a more exact name. Not only is the content of SiO_2 higher, but also that of the alkalies, especially potassium, and then also P; on the other hand iron and especially calcium and magnesium are distinctly low. No. 17 is a transitional form. The high figure of 1.59 per cent P_2O_5 for No. (16) is particularly conspicuous.

The rocks of the Slamat, especially the basalts are not so divergent in composition; the following selection (see Table 20, page 32) was made from analyses of them.

Here on the Slamat the differences with increasing SiO_2 content are not by far so strongly marked as on the Tengger; P_2O_5 even decreases instead of increasing; there is thus no standard to be established; potassium increases but slightly and iron, magnesium and calcium decrease less strongly.

These two last tables 19 and 20 are somewhat fully reproduced here, since presumably very many Javan rocks, which serve as parent material for soil formation will, on analysis, show similar figures. These give us now a first point of departure.

* * * * *

Table 20

ANALYSES OF BASALTS AND RELATED ROCKS FROM THE SLAMAT VOLCANO

Name	Olivine basalt	Hypersthene basalt	Olivine basalt	Basalt	Hypersthene andesite	Hypersthene andesite	Hypersthene andesite
Origin	Mt. Slamat	Mt. Slamat	Mt. Slamat	Mt. Slamat	Mt. Slamat	Mt. Slamat	Mt. Slamat
Own No.	(47)	(48)	(53)	(56)	(57)	(61)	(64)
Analyses from	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber	Reiber
SiO_2	48.98	49.24	50.48	52.30	53.94	55.86	58.74
Al_2O_3	20.42	19.04	17.70	18.48	18.06	18.10	17.28
Fe_2O_3	2.23	7.40	3.71	2.09	2.27	3.11	3.72
FeO	6.38	2.64	6.30	6.38	4.81	4.31	2.58
MgO	4.45	4.37	5.76	5.03	3.88	3.67	2.60
CaO	9.62	8.06	9.40	9.09	7.06	7.49	6.89
Na_2O	3.32	2.92	3.12	3.26	3.47	3.60	3.67
K_2O	1.45	1.09	1.05	1.12	1.92	2.00	1.88
H_2O +	0.19	2.33	0.28	0.25	1.52	0.19	0.71
H_2O -	0.12	1.02	0.09	0.09	1.32	0.14	0.62
TiO_2	2.47	1.65	1.70	1.65	1.30	1.41	1.23
P_2O_5	0.48	0.48	0.55	0.30	0.31	0.30	0.22
Cl	trace		trace	trace	trace	trace	trace
MnO	0.14	0.12	0.19	0.17	0.12	0.11	0.10
Total	100.25	100.36	100.33	100.21	99.98	100.29	100.24

The recent volcanic ash coverings of Java and, as far as studied, also those on the other islands deserve special mention.

* * * * *

The oldest ash analysis is certainly that by Thom. Horsfield[30]; it is of an ash which fell at Batavia on the 6th and 7th of April, 1803, and is said to have come from Mt. Goentoer. In 200 grains of sand Horsfield found:

158 grains silica (inclusive minerals, insoluble in "aqua regia" and sulfuric acid!):
13 Alumina (including TiO_2?)
10 Iron (inc. FeO)
5 Magnesia (MgO)
12 Calcareous earth (CaO)
198 and 2 loss (including alkalies, in so far as not in the "silica")

* * * * *

30. Thom. Horsfield, Scheikundige ontleding van een Vulkaansch Zand., Verh. Bataafsch Gen. der K. en W., VII (1814), No. III, p. 1-5.

Since the question was not gone into, as to what was included under "silica," we can draw from this analysis no further conclusion.

Another ash, erupted by Mt. Goentoer on the 25th November 1844, was collected by F. Junghuhn and was analyzed by P. J. Maier. The analysis was published in the Nat. en Geneesk. Archief voor N.-I., and mentioned by D. W. Rost van Tonningen[31] in connection with two analyses which he himself made of ash from the "Vuurberg van Ternate" and Mt. Merapi. He records (see Table 21):

Table 21

ANALYSES OF VOLCANIC ASH

	Mt. Goentoer	Piek van Ternate		Merapi
Specific gravity of the ash	2.857		2.733	2.801
Silica....................	51.77		31.67	43.13
Alumina....................	25.77		46.48	32.90
Iron Oxide................	13.67		14.68	10.74
Lime......................	7.44		4.77	7.39
Magnesia..................	0.94		0.53	2.23
Sulfuric acid.............	0.017		0.296	1.10
Hydrochloric acid..........	0.020	Chlorine	0.206	0.09
Water......................	0.32	Loss on Ignition	0.99	1.29
Soda and loss..............	0.06		0.38	1.38
	100.00		100.00	100.00
Analysis by................	Maier	Rost v. T.		Rost v. T.

These analyses are more interesting than valuable. It is true not only are P_2O_5 and TiO_2 not recorded, but not even the alkalies are given separately. Moreover, an Al_2O_3 content of 46.48% strikes one as being quite unusual.

An analysis of ash (of November, 1856) by Rost van Tonningen[32] apparently coming from one of the volcanoes of North Sumatra[33] gives besides perhaps a few accurate figures, yet also some strange ones, for next to a SiO_2 content of 50.40% stands an Al_2O_3 content of 27.49%, while for alkalies etc., 0.12% is given. It is peculiar that for "water soluble" 3.12% is recorded; for the three analyses above this was respectively 0.3%--1.60% and 1.42%.

In 1864 S. A. Bleekroode[34] published the results of a chemical investigation of the volcanic ash of the Kloet, which fell at Magelang on the 3rd and 4th of January, 1864. The analysis which was carried out by this military pharmacist "upon the invitation of the Chief of the Medical Service," cannot be entirely relied upon. The specific weight stated as 5.82 is obviously far too high. Again, this investigator employed partial solution with acids, and determined no TiO_2, no MnO, no FeO, but he was the first to record potassium:

Silica..................	51.545
Alumina.................	23.415
Iron oxide..............	13.755
Lime....................	5.625
Magnesia................	1.613
Potash..................	0.859
Soda....................	1.978
Water...................	0.927
Salts soluble in water..	0.232
Loss....................	0.051
	100.000

31. D. W. Rost van Tonningen, De vulk. asch van den berg Merapi, enz., Nat. Tschr. v. N.'I., II (1851), p. 464.
32. Scheik. Onderz. v.e. vulkan. asch, gevallen 14 Apr. 1856 op het fregat "Palembang," enz., Nat. T. schr. v. N. I., XII (1856/'57), p. 471.
33. According to A. Wichmann probably from the Boer ni Tellong (Eruption of 13/14 Apr. 1856).
34. Geneesk. T. schr. v. N. I., XI (1864), p. 344-349.

The figure here given for "alumina" is also quite too high.

Ten years later J. B. Nagelvoort[35] wrote a "contribution regarding the so-called volcanic ash in general, and in particular about that of the Merapi in Java of 15th and 16th April 1872." In this somewhat copious but important paper much foreign literature was for the first time incorporated critically and carefully. Nagelvoort also demonstrated for the first time manganese and titanium in volcanic ash from Java; very likely he is also the first of the investigators in Java, who recorded the microscopic study and demonstrated in the ash the presence of feldspar, augite, hornblende, as well as magnetic iron ore and blown glass. But he did not give a quantitative chemical analysis.

The analysis by C. L. Vlaanderen[36] of ash erupted by Gedeh (Java) on the 18th September 1866, and "collected on the crater wall by Dr. Ploem," also sub-divided the material into three parts: the water soluble constituents 2.76%, the hydrochloric acid soluble constituents 29.47%, and the residue insoluble in hydrochloric acid 67.47%. By combining the two latter portions the following composition was found:

SiO_2	58.54%
Al_2O_3	20.00%
Fe_2O_3	7.36%
FeO	0.69%
MgO	0.42%
CaO	5.95%
Na_2O	0.53%
K_2O	6.10%
H_2O	0.47%
	100.06%

Here for the first time we come across FeO determined separately, as well as Fe_2O_3; (however the amount is apparently still too low). K_2O is presumably also too high with respect to the Na_2O content. From Mt. Gedeh material there exists not a single additional analysis for comparison.

Verbeek recorded in 1883[37] still another analysis of the Merapi (Sumatra's West Coast) of December, 1876. This ash he described as "augite andesite dust." But this analysis by Clausnizer cannot be thoroughly relied upon:

SiO_2	58.31
Al_2O_3	12.01
Fe_2O_3	6.41
FeO	0.97
MgO	2.47
CaO	11.99
Na_2O	4.13
K_2O	2.00
H_2O (loss on ignition)	1.56
Total	99.85

Beside the high Fe_2O_3 figure, the FeO figure is conspicuously low, and Al_2O_3 likewise seems conspicuously small compared with the recorded amounts of alkali and the extraordinarily high calcium content. Moreover MnO, TiO_2 and P_2O_5 were apparently not determined. Such an analysis is an invitation for a repetition according to modern analytical methods.

In 1894 P. van Romburgh[38] investigated ash of Mt. Galoenggoeng erupted on the 18th and 19th October of that year. This ash fell at Garoet, and also in three other places. However he did not carry out any complete analysis, but merely determined the quantity of calcium, magnesium, potassium, and phosphorus which were extracted by acid. The investigation was for the sole purpose of determining whether the ash contained constituents immediately injurious to plants, or whether on the other hand the ash might be thought of as a fertilizer; the ash was found to be neither injurious nor beneficial.

The eruption of the Kloet on 23rd May, 1901, was the introduction to the publication of different investigations of the ash. Kramers[39] extracted different samples of ash with 5% hydrochloric acid. From the agronomic point of view these figures are quite important, but from the standpoint of the composition of the ash

35. Nat. T. schr. v. N. I., 34 (1874), p. 1.
36. Jb. Mijnw. N. I., 1873, I, p. 219-221.
37. R. D. M. Verbeek, Sum. Westkust (1883), p. 518-519, Beschrijving der asch, p. 496.
38. Teysmannia (1894), p. 711; Ref. Arch. Java. S. Ind. (1895), I, p. 387.
39. Teysmannia, (1901), p. 313; Ref. Arch. J. S. I. (1902), p. 30.

as a whole they are insignificant. For the ash which fell at Ngoesri, located on the slopes of the Kloet, he recorded a silicic acid content of 56.5 per cent. Prinsen Geerligs[40] it is true, gave a total analysis, but it is not fully divided up into the constituents, and besides it is not clear whether he was dealing with ash which had fallen at Kediri, at Banjoemas, or at Pekalongan, or whether it was a mixture of the three (or even four) kinds. These analyses will be found in Table 22.

The high silica content leads one to presume that he studied ash which fell far from the volcano; or that in the final mixture the ash from Banjoemas and/or Pekalongan greatly predominated. Iron dioxide and alumina which were not separated, are strikingly low; calcium is very high. The quantities of SO_3 and P_2O_5 are apparently only those soluble in hydrochloric acid; Cl is the water-soluble amount, judging from the constituents mentioned which are soluble in water and in hydrochloric acid. In short--these analyses leave open many important questions.

One gets more of a foothold from the data of Kobus,[41] especially since he investigated separately the ash from five places, at air line distances of 20, 40, 90, 220 and 320 km. from the point of eruption. (The analyses were made by Th. Marr). It is true that total analyses were made of only three of the five ashes, and even then only incompletely, but yet what is given is of value. (See table on page 36). It appears clearly how, with increasing distance from the point of eruption and consequently with finer ash, the silicic acid content increased, and probably also that of the alkalies, while the figures for Al_2O_3, Fe_2O_3, CaO and MgO decreased.

Kobus also referred to a couple of analyses by Van Lookeren Campagne[42] which are of ash from the Merapi (Central Java), compared with "andesite," i.e., a mixture of three rock samples from the volcanoes Merapi, Lawoe, and Sawal (Cheribon), and "basalt" which is a mixture of basaltic lavas from the Oengarang, the Slamat and the Goentoer. We can give only a comparative value to the last two analyses, since we have no way of knowing which "hand samples" had the greatest influence upon the figures. Although the analysis of the Merapi ash is incomplete, because of the failure to determine the Fe_2O_3, FeO and TiO_2 and the total 101.17 is somewhat high, still the results are included in Table 22. The relatively high potassium content of these andesitic ashes is peculiar.

In this table (Table 22) a place is also made for two partial analyses of Lemongan·ash[43]; as well as an old analysis of Prölls.[44]

In conclusion there may be found in the exhaustive monograph of Kemmerling[45] on the Kloet eruption of 19/20 May 1919, four analyses of ash from the eruption; these too are not complete analyses, but yet worth recording and therefore included in Table 22. In these analyses there may be noted particularly: the high content of Al_2O_3, the low P_2O_5 content, the absence of the alkalies, of TiO_2 and FeO. A repetition of the analyses filling up the necessary gaps, would not be a superfluous luxury (see Table 22).

* * * * *

Since in these analyses the sulfur content is never determined, we may, in order to fill in the gap, refer to the following quotation from White:[46] "total sulfur" was determined according to the method of Hillebrand:[47]

40. Arch. J. S. I. (1902), p. 56.
41. J. D. Kobus, Arch. J. S. I. (1902), I, p. 97-108.
42. C. J. van Lookeren Campagne, De bouwgrond van Java, enz., Hand. le Congr. Alg. Synd. Suiker-fabr., (Soerabaia, Mrt. 1896), p. 20-41.
43. Kobus, l. c., p. 105.
44. N. Jahrb. f. Min. etc. (1864), p. 426.
45. Vulkanol. Meded. No. 2, (Batavia, 1921), p. 49.
46. J. Th. White, Voork. v. voor kultuurgew. schad. best, in Kloetasch, Med. Lab. Agrogeol. en Grondond. No. 6, (Batavia, 1920), p. 10.
47. W. F. Hillebrand, Analysis Silic. and Carbon. Rocks, U. S. Geol. Surv. Bull. No. 422, (1910), p. 198.

Table 22

ANALYSES OF ASH FROM KLOET, MERAPI, AND LAMONGAN VOLCANOES

Volcano	Kloet	Kloet	Kloet	Kloet	Kloet	Kloet	Kloet	Kloet	Kloet	Merapi (M. Java)	Lamongan	Lamongan (?)
Time of the eruption	1864	23/5-1901	23/5-1901	23/5-1901	23/5-1901	20/5-1919	20/5-1919	20/5-1919	20/5-1919	1896(?)	1896	1902
Place of collection		Modjopang-goeng	Madioen	Klampok	Pekal-longan	Gambar lowest layer	Gambar uppermost layer	Petoeng Ombo	Malang		Pasoeroean	Pasoeroean
Distance from the point of eruption		49 K.M.	95 K.M.	320 K.M.	310 K.M.	10 K.M.	10 K.M.	9 K.M.	36 K.M.		65 K.M.	65 K.M.
Analyzed by	Prölls	Marr	Marr	Marr	Pr. Geerligs	Lab. Mat. Ond. B.O.W.	Lab. Mat. Ond. B.O.W.	Lab. Mat. Ond. B.O.W.	Lab. Mat. Ond B.O.W.	Van Lookeren Campagne	Marr	Marr
SiO_2	52.32	51.9	56.4	62.8	66.70	57.46	54.62	54.35	54.98	56.68	50.70	59.70
Al_2O_3	20.01	22.0	18.5	18.2	12.82	20.15	21.20	22.02	21.58	26.32	19.70	17.96
Fe_2O_3	not det'd	10.1	7.5	5.4		8.16	9.20	8.92	8.64		12.40	8.84
FeO	not det'd											
MnO	not det'd	not det'd	0.4	not det'd	not det'd	0.61	0.37	0.36	0.32	0.23	not det'd	not det'd
MgO	5.26	3.2	3.7	1.9	2.90	2.77	4.49	3.25	3.36	1.82	3.85	2.34
CaO	7.16	10.6	10.3	6.0	10.80	7.59	9.20	9.315	9.30	7.62	10.60	6.40
Na_2O	3.74	not det'd	1.8	not det'd	4.24	not det'd	not det'd	not det'd	not det'd	6.14	(2.75)	(4.76)
K_2O	1.11	not det'd	0.7	not det'd	0.71	not det'd	not det'd	not det'd	not det'd	2.09		
H_2O + ...	not det'd	0.6	0.4	0.9	0.42	0.80	0.40	0.40	0.50	not det'd	not det'd	not det'd
H_2O -	1.25	0.3	0.2	0.4		not det'd	0.24	not det'd	0.25	not det'd	not det'd	not det'd
TiO_2	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	trace	trace	trace	not det'd	not det'd	not det'd
P_2O_5	not det'd	not det'd	0.5	not det'd	0.07	0.083	0.06	0.075	0.06	0.27	not det'd	not det'd
SO_3	not det'd	not det'd	0.4	not det'd	0.66	0.95	0.22	0.39	0.26	trace	not det'd	not det'd
Cl	not det'd	not det'd	not det'd	not det'd	0.05	trace	trace	trace	trace	trace	not det'd	not det'd
S	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd	not det'd
	---	98.7	100.8	95.6	99.37	---	---	---	---	101.17	100.00	100.00

These figures (see Table 23) thus include the sulfur, which is present as sulfate, as well as the sulfur in the forms of pyrite (FeS_2) and "pyrrhotien" (FeS). These amounts vary rather widely, but the number of analyses is not great enough to draw any general conclusion from them; meanwhile they are of such an order that we cannot but be sorry to find in the ash analyses in Table 22 so frequently the expression "not determined."

Table 23

SULFUR CONTENT OF KLOET ASH SAMPLES

Serial No. Lab. of Agrogeology and Soil Research	Ash of Kloet, 1919 collected at:	Total Sulfur % of the air dry ash
7048	Gambar Plantation upper layer......	0.31
7047	Gambar Plantation lower layer......	0.84
7043	Kediri.............	0.31
8271	Tjilatjap..........	0.21
7049	Malang.............	0.22
7039	Bondowoso..........	0.41

More recent analyses of ash from Mts. Gedeh, Tangkoeban Prahoe, Goentoer, Papandajan, Galoenggoeng, Merapi, Smeroe, Bromo, Lamongan, and Raoen are not yet to be found in the literature. It is to be hoped that these gaps which at present we regret to find when studying the soil may within a few years be filled in!

* * * * *

We cannot very well leave the subject of the eruptive rocks without a short treatment of that group of potash-rich leucite rocks, which have appeared in Java on Mts. Moeriah, Ringgit and Loeroes, and have also been found in Celebes, from Maros to Watoe Soppeng and still farther north, and also on Bawean and then on Soembawa. These rocks especially attracted the attention of petroleum geologists such as C. F. Iddings, of Washington; we have to thank this interest for a large number of good analyses of these rocks. To record them all here would seem superfluous, but a few principal representatives are included in Table 24.[48]

* * * * *

In these figures, we see that most of these rocks exhibit a high content of potassium; a few (Nos. 18 and 19) have less and therewith demonstrate the variability. Among the rocks of Moeriah as among those of the Piek van Maros, those richest in silica also have the most alkalies and aluminum: in Celebes P appears to accompany Fe, Mg, and Ca, thus the most phosphorus is in the basic rocks; also the basic Moeriah rocks exhibit quantities of P. As regards almost all the main constituents, the Celebes rocks fall into clearly defined groups; of the Moeriah no more acid rocks have been analyzed than the above-named.

Except for the high P content of the more basic of these rocks, the attention might well be directed toward their high Ti content.

* * * * *

48. Jos. P. Iddings, Igneous Rocks, New York, 1913, II, p. 619-631 (Neth. Indies); J. P. Iddings & W. E. Morley, Contrib. petrogr. Java and Celebes, J. Geol., Chicago, 23 (1915), p. 231-245.

Table 24

ANALYSES OF POTASH-RICH VOLCANIC ROCKS

Name.......	Leucite-tephrite	Leucite-tephrite	Leucite-tephrite	Leucite-tephrite	Bostonite	Sodalite trachyte	Biotite nephelinite syenite	Absarokeit	Biotite shonkinite	Marosite
Origin.....	Moeriah	Moeriah	Moeriah K.Gibinan	Moeriah at Ragoe	P. v. Maros Gentoengan	P. v. Maros in the South West	P. v. Maros	P. v. Maros in the South West	P. v. Maros	P. v. Maros Gentoengan
Own No. ...	(1)	(2)	(6)	(8)		(12)	(13)	(18)	(15)	(16)
Analyzed by	Morley	Morley	Morley	Morley	Hinden	Morley	Morley	Morley	Morley	Morley
SiO_2	51.85	50.18	46.54	45.03	61.15	58.61	56.31	46.05	45.26	43.98
Al_2O_3......	19.08	17.82	15.95	16.59	22.07	21.62	21.69	14.88	15.70	12.28
Fe_2O_3......	4.25	4.04	5.24	4.55	1.05	1.16	1.20	4.22	2.44	3.49
FeO	2.69	3.89	5.51	6.37	1.02	0.79	0.97	5.78	6.16	7.70
MgO	1.48	2.88	4.70	3.95	0.40	0.16	0.54	5.98	8.28	8.00
CaO	5.81	7.19	10.09	11.09	0.75	1.71	1.88	13.47	11.95	11.19
Na_2O	4.46	3.24	2.28	3.53	5.86	6.60	5.56	1.41	1.73	1.33
K_2O	6.61	6.65	4.44	5.29	7.01	6.82	9.17	2.56	3.42	5.06
H_2O +......	1.04	1.51	1.11	0.49	0.71	1.42	1.13	3.01	1.41	1.61
H_2O -......						0.19		0.52		0.21
TiO_2	0.66	0.76	1.11	1.10	0.20	0.17	0.41	0.93	1.66	2.24
P_2O_5	1.23	0.76	1.18	0.96	not det'd	0.04	0.31	0.59	0.90	1.81
Cl	0.21	0.16	0.07	0.26	not det'd	0.07		0.09		F 0.15 0.12
MnO	0.51	0.30	0.18	0.64	not det'd	0.40	0.16	0.21	0.34	0.51
BaO	0.17	0.25	0.13	0.16	not det'd	0.01		0.06		0.16
SrO	0.19	0.29	0.24	0.16	not det'd	0.02		0.07		0.12
Misc.......	0.11	0.04	0.16	0.16	not det'd	0.02	0.57	0.04	0.55	S 0.10
	100.40	100.01	99.53	100.33	100.22	99.81	99.72	99.90	99.80	99.97

As to the analytic data relating to sedimentary rocks of the Netherlands Indies, the position even today is still very distressing. It is true that a few partial analyses may be found,[49] but apart from a few exceptions, which therefore may also here be recorded[50] one searches in vain for complete analyses.

Here we have an analysis of a blue claystone, which when submerged in water increases about 10% in volume:

SiO_2	50.70%	
TiO_2	1.12%	
Al_2O_3	17.47%	(including the P_2O_5 present? if any)
Fe_2O_3	5.63%	(including the FeO present? if any)
MnO	0.56%	
MgO	0.91%	
CaO	9.76%	
Na_2O ..... K_2O	1.24%	
Moisture...	4.44%	(including loss on ignition)
CO_2	4.38%	
SO_3	3.90%	
	100.08%	(this should be 100.11%)

49. Jb. Mijnw. (1930), Alg. Ged., p. 252, No. 2 to 6; relating to claymarls from Central Java.
50. E. A. Douglass, Onderz. oorz. grondw. spoorb. Poerw.-Padal. enz., Jb. Mijnw. N.-I. (1911), Verh., p. 238.

The "clay stone" is "presumably formed from volcanic ash which had settled out from suspension in water",[51] it contains limestone masses and long thin white lenses of tuff. In comparison with the analyses of the eruptive rocks it strikes one that in contrast with such a high content of calcium there are such low amounts of alkalies. If one takes from the quantity of Ca as much as is necessary to combine with SO_3 and CO_2, to form calcium carbonate and anhydrite or gypsum, then there still remains an excess of 1.56% CaO. We remain entirely in the dark as to what to think of the way in which constituents of the claystone are combined into minerals. From the figures it ought to be easy to compose a magmatic "rock"; yet actually this is not the case, for such a rock does not swell up in water, not even in a finely powdered form, though the claystone does; ultimately it forms a plastic mass.

This example well demonstrates how a complete analysis by itself has only a small value. There must still be added all kinds of other data.

Total analyses, as well as partial ones are entirely lacking for aerial tuffs, quartz sandstones, marine sandstones, and tuffaceous calcareous sandstone of the Netherlands Indies, from which we could learn how much quartz, clay, carbonate, and tuffaceous or volcanic material they possess.

* * * * *

Table 25

ANALYSES OF METAMORPHIC ROCKS

Name..........	Quartzite	Mica schist	Glaucophane schist	Muscovite epidote schist
Origin........	W. Borneo	Karangsamboeng, Central Java	K. Trenggoelon Central Java	Upper course of the Loh Oeloh Central Java
Own No.	(21)	(28)	(30)	(35)
Analyzed by...	Willems	Esenwein	Den Haan	Den Haan
SiO_2	98.22	70.87	52.06	40.77
Al_2O_3	1.27	12.85	11.66	19.60
Fe_2O_3	0.12	0.72	4.02	2.07
FeO	0.15	4.65	5.67	12.61
MnO	0	0.12	0.07	0.29
MgO	trace	1.83	10.10	4.36
CaO	0.01	1.54	2.93	9.88
Na_2O	0.04	2.63	4.56	0.77
K_2O	0.31	2.20	2.42	2.74
H_2O + ...	0.12	1.60	2.80	2.42
H_2O -	0.06	0.10	0.02	0.06
CO_2	0	0	1.78	0.23
TiO_2	trace	0.94	1.82	3.02
P_2O_5	0.01	0.19	0.26	0.78
	100.01	100.24	100.17	99.59

51. L. c., p. 229.

Only a few analyses of metamorphic rocks, mostly from Central Java, are available.[52] A few analyses from Rittman[53] concern special cases which are of minor importance for general soil science. It is also true that the rocks to which the following analyses (Table 25, page 39), refer are not of great significance in soil formation, yet these kinds occur upon Sumatra, Borneo, Celebes, New Guinea, etc. and here and there they are most certainly a parent material for soil formation:

These few analyses (see Table 25) demonstrate sufficiently, how much variation also exists in this group of rocks; of each of the constituents little or much may occur. The variability in minerals is greater than in the case of the volcanic rocks, but many of the minerals are only accessory or seldom occur. Quartz, mica, secondary feldspars and various sorts of amphiboles compose the main mass of the minerals. As compared with the volcanic rocks a principal difference is, however, the absence of glass, which renders them less resistant against weathering.

* * * * *

We have gone through the parent materials of the kinds of soils of the Netherlands Indies which in general are the most important. But a great many rock analyses are still needed to enable one to answer practical questions such as where in Java or in Sumatra, etc., one might, for example, expect to find soils, which in their origin are rich or poor in phosphorus, or potassium, or calcium? It is welcome news that during the last few years the Petrochemical Laboratory of the Geological Survey has been established and is in operation at Bandoeng, Java; without doubt its work will also be of increasing value to soil science in the Netherlands Indies.

* * * * *

52. Jb. Mijnw. N. I., (1930), Alg. Ged., p. 253-257.

53. A. Rittmann, Gest. v. Kellang u. Manipa (Ceram), (Amsterdam, 1931). (Geol. Petrogr. Palaeont. Results Explor. Ceram by Rutten & Holtz).

Chapter II

THE ACTIVE FORCES OF SOIL FORMATION:

FORMS OF CLIMATE ———— SOIL FORMATION

From the rocks, directly or indirectly, the soil originates through weathering and soil formation, two processes which merge into each other, in these processes the active forces are those of the weather, locally defined as climatic influences. The climate is conceived of as all of the climatological characteristics at a given place on the earth.

In considering the climate and the influence of the climate, from the beginning we must make a sharp distinction between the climate in the atmosphere above the soil, and the climate in the soil, the soil climate. The soil particles are directly affected only by the latter; and indirectly with the former only in so far as through it the latter is influenced.

The climate, let us say the atmospheric climate, is studied by the meteorologists and climatologists with instruments which are located meters above the soil; many times anemometers and sunshine recorders are on the roofs of high structures. Everyone knows that at a short distance, say only 5 or 10 cm. above the soil there are entirely different values for temperature and humidity than farther, say 1 to 3 meters above; it may happen that plants are frozen by night frost, at a few degrees below zero C, while the "air temperature" about 2 meters higher up is still a few degrees above zero C. When dry wind suddenly starts to blow the relative humidity can fall to below 30 per cent, so that some living plants dry up, while at 20 cm. below the surface the soil may still be saturated. Examples such as these can easily be increased with a number of others; enough to demonstrate the fact that what happens climatologically above and in the soil differs so much that it accounts for the differentiation in principle of the soil climate from the air climate. Differentiation does not, however, mean that the two are entirely independent from each other; for everyone knows that with a sustained higher or lower temperature of the atmosphere the temperature of the uppermost portion of the soil also rises or falls, even though it be in a different temperature range. Also with a goodly rain the soil becomes more moist, and with a long continued drought the atmosphere of the soil dries out. A necessary consequence of the differentiation is that both the air and the soil climates must be individually investigated, after which the mutual relationships appear. At the same time one may be sure that it will be evident that there are certain factors which either may be of great weight, or which will have little or no significance, and vice versa.

The climate as such is a complex system, which cannot be directly measured. It rather consists of a number of climatic factors, of which each in itself is quite measurable, and as such can be studied scientifically. So what we shall discuss here are various climatic factors, which are known to be of influence upon the soil and that occur within the soil. These factors are principally temperature, humidity, and indirectly the relative humidity of the air, the wind (monsoons), cloudiness, etc. In addition, in connection with soil climate, the condition of the vegetation is of particular importance. Perhaps there are still other factors which are important but if so, we do not yet know what they are.

1. SOIL TEMPERATURE

The temperature of the atmosphere, as is dealt with by Braak[1] in his handbook

1. C. Braak, Het Klimaat van Ned.-Indië, Verh. 8 v/h Kon. Magn. Meteorol. Observ. te Batavia, Dl. I, Afl. 5. Hist. VIII, (Batavia, 1924).

regarding the climate of the Netherlands Indies, are data relating to the atmosphere a few meters above the soil, as measured in the shade. If the soil is screened from the radiation, as for example in a thick forest, then the surface few mm. of the soil follow the air temperature but with somewhat less variation. But--if direct radiation becomes a factor then enormous differences in temperature occur.

For Central Europe there are available extensive series of observations; J. Schubert, especially, has undertaken and published many investigations[2] for that region. From these data it appears that at midday the soil temperature may be more than 13°C warmer than the corresponding air temperature; for Kurwien (East Prussia) there has been recorded a maximum temperature of 43.1°C[3] while somewhere else is mentioned "a radiation intensity of 1.278 Cal/cm²/min, corresponding with a temperature of 80°."[4] Even though this temperature was not directly measured on the radiated object--the soil, still we find this statement by Vageler:[5] "Pechuel-Loesche and Vageler have actually recorded temperatures of 84°-86°C. for the soil surface in the Congo and in East Africa, and similar figures have been registered in other tropical and subtropical regions."

Other observations in East Africa[6] by the same writer gave for bare soil, surface temperatures of 50.20; 51.3° and 54.2°C; but at only 5 cm. depth below the surface the temperature did not rise above 37°C, and at 10 cm. depth the temperature came only just above 30°C.

Corresponding with the above-mentioned maxima of over 50°C, under a growth of grass (savanna) the soil surface temperature was only just 34°C, and at the same time in a neighboring shady forest not more than about 25°C. If we take into consideration that the air temperature at the same time gave maxima of 26-30°C, then it appears how the surface of bare soil can be 20 to 25°C warmer. Any sort of vegetation, however, reduces this difference.

At Pusa, British India, Leather took soil temperature measurements[7]; he pointed out, as a general rule, that with dry weather and a cloudless sky the maximum temperature of the bare soil at the surface is approximately 20°C higher (plus or minus 5°C) than the maximum temperature of the air as observed normally in a meteorological shelter. The minimum temperatures, according to Leather, do not shift much. At a depth of only 1" (2.5 cm.) such marked differences are no longer found; at this depth the day temperature of the bare ground is but approximately 3°C higher than that of the atmosphere, and the night temperature about 2°C higher.

If the above temperature ranges are also true for the Netherlands Indies, then we might conclude from it that with atmospheric temperatures of 25° to 30° or 35°C (taken in a meteorological shelter), the surface temperatures of bare soil will often be between 45° and 60°C, but that at the same time under forest the soil temperature will not rise far above 30°C.

In Tonkin[8] it was established that on an average under shady conditions the soil temperature, at 15 cm. depth, during a year was approximately 2°C higher than that of the air, while at 50 cm. depth, it was 4.5°C higher. Corresponding observations on bare land in the direct sunlight are lacking.

Now as far as the Netherlands Indies are concerned, Braak records[9] that observations made in Batavia in an open lawn indicated for a depth of from 3 to 5 cm. an average temperature of 3°C above the average air temperature, for depths of 15 to 110 cm.

2. J. Schubert, Das Klima d. Bodenoberfläche u. d. unt. Luftschicht i. M.-Europa, Handbuch der Bodenlehre (Berlin, 1930), Bd. II, p. 55-91; J. Schubert, D. Verhalten d. Bodens gegen Wärme, ibidem: Bd. VI, p. 342-375. There is also much other literature but relating practically exclusively to Central Europe.
3. Handbuch der Bodenlehre VI, p. 355.
4. Handbuch der Bodenlehre II, p. 57.
5. P. Vageler, An Introduction to Tropical Soils, translated by H. Greene (London, 1933), p. 104.
6. P. Vageler, Die Mkatta Ebene, Beih. z. trop. Pfl. (1910), p. 266-278.
7. J. Walter Leather, Soil temperatures, Mem. Dept. Agr. India (Chem. Ser.), IV, 2 (1915), pp. 19-49.
8. P. Carton, Temperature du sol à Phu-Lien (Tonkin), Bull. Écon. Indochine, 33 (1930), p. 688 B.
9. C. Braak, Klimaat v. Ned.-Indië, I, p. 332, (Verh. Magn. Meteor. Obs. Bat. No. 8, Batavia, 1921-25).

of $3\frac{1}{2}^{\circ}C$ above. At 5 cm. depth the absolute maxima varied between 35° and $38^{\circ}C$.

From determinations by Marr[10] we learn that on the grounds of the sugar experiment station at Pasoeroean the soil at 1 foot (30 cm) depth averaged approximately $3.5^{\circ}C$ warmer, and at 2 to 4 feet approximately 3 2/3°C warmer than the atmospheric temperature. Nothing is recorded as to the state of the vegetation, if any, on the land.

Observations made at Buitenzorg, by Van der Elst,[11] above and under a lawn exposed to the full sun, agree very closely with those obtained by Braak at Batavia. Here, too, was found an average soil temperature $3.3^{\circ}C$ higher than the corresponding air temperature.

Since observations made by J. van Breda de Haan[12] at an earlier date later appeared to be incorrect,[13] they will not be discussed here.

It is worth while to record here two series of observations by R. Wind[14] with reference to the influence of different crops or covers, in short--the effects on soil temperature of hampering the radiation.

1. He took the temperatures at Buitenzorg at noon at 1 to 2.5 cm. depth:
   a. in an open field, where there was an average temperature of $36.6^{\circ}C$ (Max 40°--Min $32^{\circ}C$)
   b. under a light crop of maize: temperature of $26.0^{\circ}C$ (max $27^{\circ}C$--min. $25^{\circ}C$)
   c. under a mat cover: temperature $25.3^{\circ}C$ (max. $26^{\circ}C$--min. $24^{\circ}C$)
2. He checked the temperatures at the same depth, at another time, and found:

in the full sun		
	Maximum $44^{\circ}C$	minimum $22^{\circ}C$
in light shadow		
	Maximum $30^{\circ}C$	" $21^{\circ}C$
in heavy shadow		
	Maximum $26.5^{\circ}C$	" $21^{\circ}C$

The striking feature of these observations is that the day maxima vary so much more widely than the night minima. With the exposure and the nature of the soil surface as it is, one would expect that during the day the temperature would rise strongly, and that at night the cooling down through proportional radiation would also bring it back to equilibrium, and thus the average temperature would come to the same thing. This however, does not appear to be the case. In the supplement to the handbook of Braak[15] are also recorded a number of observations pertinent in this consideration:

The average soil temperature under a large shade tree at a depth of 30 cm. appeared to be pretty near the same as the average air temperature. According to observations at Tjibodas (1,450 m), this is likewise the case under "tropical high forest," and even near the top of the Panggeranggo, at almost 3,000 m. elevation.

The difference is insignificant between bare ground and soil with grass on it. In both cases--as above already recorded--the temperature at 30-60 cm. averaged approximately 3°-4° higher than the corresponding air temperature.

* * * * *

Yet the difference becomes still much greater under a dark-colored, strongly heat-absorbing surface layer, such as for example, asphalt; a series of observations from the Observatory at Batavia showed an average temperature at 60 cm. depth to be $11^{\circ}C$ higher than the average air temperature. It is generally known that the temperature in the surface layer of asphalt in the full sun can rise to an extraordinary height, however figures have not been obtained of that maximum temperature; they must go well above $70^{\circ}C$, but how far above is not known.

10. Th. Marr, Meded. Proefst. Java Suik. Ind. No. 8, Overgen. in Arch. Suiker Ind., I (1911), p. 541.
11. Referred to by Braak, l. c., p. 334.
12. Observ. météorol. d. Jard. Botan. d. Buitenzorg, 1901-1909.
13. Jaarb. Dept. Lb., 1913, p. 74.
14. Tectona XIV (1921), pp. 420 and 425-426.
15. L. c., pp. 512-515.

Now asphalt is an artifical product, and paving with it is the work of man. In the absence of artificial conditions, however, one also comes across conditions which lead to high temperature. For example, the upper surface of dark colored stones on which the sun shines, especially of boulders in a river bed, are often colored black with a superficial layer of iron and manganese oxides. Unfortunately temperature observations concerning such have never been made. It is true that the geological, geomorphological and geographical literature is full of communications concerning the intense heating of bare rock by the sun during the day in the mountains and still more of the effects observed in the desert, including the cooling off at night, and the intensive physical weathering resulting from this; but in the publications I have consulted, temperature records corresponding with those phenomena--(such temperatures are indeed not at all easy to measure) are entirely lacking.

Two phenomena which it is true, have already been long known in Central Europe[16] have been gone into for the Netherlands Indies by Braak.[17]

1. The heating of the deeper soil layers from the surface takes time, hence the maximum shows a lag in proportion to the depth (see Table 26):

Thus the heat moves rather regularly downward, so that at 15 cm. depth the maximum occurs 6 hours later than at the surface, and at 30 cm. 12 hours later; there is less lag of the minimum at the lesser depths (see Table 26); at 15 cm. depth it is found 3.5 hours later, at 30 cm. depth 7 hours later. At 30 cm. (1 foot depth) the temperature varies only little, as is shown below, though at 15 cm. it is yet still noticeable. When we consider the significance of soil temperature for plants, we shall have to come back to this point.

2. The diurnal variation decreases very rapidly with the depth. The observations of Braak, under the sod at Batavia, showed (see Table 27, page 45).

At 30 cm (1 foot) depth in the tropics the soil temperature is thus already practically constant. At higher latitudes in the course of the year there are greater variations, but here in the tropics they are negligibly small.

This remarkable regularity is only disturbed by heavy cool rains, which penetrate quicker into the soil than the dry heat exchange takes place. "The temperature then falls several degrees within a few hours, even to a depth of more than 1 m., and the lower temperature persists in the deepest horizons sometimes for weeks, before the temperature gradually increases

Table 26

RELATION BETWEEN MAXIMUM AND MINIMUM SOIL TEMPERATURE AND DEPTH

Depth	Entrance Maximum Temperature	Lag	Entrance Minimum Temperature	Lag
3 cm.	13 hours (1 P.M.)		6.5 hours (6.30 A.M.)	
		1 hour : 2 = 0.5 hour per cm.		0.5 hours: 2 = 0.25 hours per cm.
5 cm.	14 " 2 "		7 " 7 A.M.	
		2.5 hours: 5 = 0.5 " " "		1 " : 5 = 0.2 " " "
10 cm.	16.5 "		8 " 8 A.M.	
		2.5 " : 5 = 0.5 " " "		2 " : 5 = 0.4 " " "
15 cm.	19 " 7		10 " 10 A.M.	
		6 " : 15 = 0.4 " " "		3.5 " : 15 = 0.25 " " "
30 cm.	1 " = 25 hours		13.5 "	
		15 " : 30 = 0.5 " " "		14.5 " : 30 = 0.5 " " "
60 cm.	16 " = 40 "		4 " = 28 hours	

16. Schubert, J., Das Verhalten d. Bod. g. Wärme., Handb. d. Bodenl. VI, p. 342-375.
17. C. Braak, l. c., pp. 336-337.

Table 27

DIURNAL VARIATIONS IN SOIL TEMPERATURE

Depth	Annual average of the daily maximum temperature	Annual average of the daily minimum temperature	Annual average of the daily differences
3 cm.	32.12	26.92	5.2
5 "	31.11	27.06	5.0
10 "	31.09	27.99	3.1
15 "	30.19	28.70	1.5
30 "	29.56	29.28	0.3
60 "	29.55	29.50	0.05

to the usual figure."[18]

* * * * *

The following is a summary of the soil temperature data for the Netherlands Indies:

At a depth of 60 cm. the temperature is essentially constant, at 1 m. depth it is certainly so; even annual variations are hardly perceptible. At this depth the temperature under forest at sea level is 25-27°C. With increasing elevation, for each 100 m. it falls about 0.6°C, so that at 1,000 m. it is approximately 20°, at 2,000 m. about 14° and at 3,000 m. about 8°C.

On open terrain (bare ground or short grass) the temperature is about 3-4°C higher, thus at 60 to 100 cm. depth at sea level it is about 28-31°C. In the course of a year the variation is seldom more than 1.5°. The absolute daily variation, at 1 m. depth is not noticeable, though toward the surface it increases strongly; at 10 cm. depth is is still but 12°, at 3 cm. slightly above 15° and the maximum about 45°, though at times it may get as high as 70 or even 80°.

Whether with increasing elevation above sea level the temperature gradient of -0.6° per 100 m. in general is maintained for soil temperatures at one m. depth in the tropics, has as yet been only slightly investigated; for the summit of the Pangeranggo the rule seems to hold good. For Tjibodas (1,450 m.) the difference between high forest and open grass land is 4°, for the summit of Pangeranggo 3°C.

As to how the surface temperatures are at greater elevations, is yet unknown. Presumably the variations from the average are toward the minimum side, greater high up in the mountains than below in the plain, so that minima below the freezing point (night frosts) occur at a lower elevation (for example 1,500 m.) than should be expected according to the gradient.

Although for soils at about 1 m. and deeper the average temperature lies between 9° and 31°, and on the surface between perhaps -15° and 80°, yet one may assuredly say that for the greatest part of the soils of the Netherlands Indies the temperature generally remains between 25° and 30°C.

* * * * *

2. THE WATER IN THE SOIL

Soil water occurs in different forms, which may be classified under the following heads:

a. water in cavities and capillaries;
b. adhering water;
c. hygroscopically combined water;
d. chemically combined water;
e. water vapor.

Each of these forms[19] has its significance, not only in the strictly

18. Braak, l. c., pp. 340-341.

19. If we do not include ice in this consideration of tropical soil conditions, presumably no one will take it amiss!

scientific studies of the soil but also in practical soil science. We should therefore consider each form separately and their mutual relationships.

a. Whenever anywhere at any particular moment one digs a pit and at any arbitrary depth observes the soil, it will almost always appear moist, perhaps even wet; a bit of blotting paper, if pressed against the soil, shows wet spots. This water exists in the soil in spaces between the solid soil particles. The structure of the soil is such that there are always more or less of the coarser or finer spaces, called the capillary spaces. There is usually some liquid water in these spaces; if not the soil is "dry" (but not therefore water free). The spaces are seldom entirely filled with water, so that the soil is "free from air."

Those cavities or spaces may be separate, but also they may communicate with each other; if they are connected in a long vertical row of very small diameter, then one has true capillaries or hair-like tubes. But there are also wider tubes.

* * * * *

b. In those capillaries and tubes water movement can take place. If the water runs out from such a tube or capillary, the walls will still be wet; in this case the remaining water is called adhering water. This water is of especial significance in coarse sandy soils.

If the water moves through tubes or capillaries, then the speed is the most rapid in the center, while towards the walls the speed decreases. The actual adhering water does not flow with the stream. From this it follows that the speed, or better said, the quantity of water, which in a given time flows through the capillaries is not proportional to the diameter of the capillary tube, but the speed decreases more rapidly than the diameter decreases. For very small capillaries the speed becomes practically zero, that is to say, in spite of the fact that capillary water is still found in the soil, it is really only continuous adhering water.

* * * * *

c. If a soil is "dry" to such an extent that both its capillary water and its adhering water have disappeared, then all the particles still remain surrounded by a mantle of absorbed water molecules, which cannot be removed with blotting paper, but which would evaporate off completely in an environment free from water molecules. If that environment contains air, air particles take its place, as occurs in a dessicator above strong sulfuric acid. Soil is thus "water attracting" or "absorbent of water vapor" or hygroscopic; and this hygroscopicity is a function dependent upon the surface. The smaller the soil particles, the greater is the surface for the same weight of soil, and so much the greater is also the hygroscopicity, expressed by percentage of weight of water per 100 parts by weight of water free soil. For sand, that hygroscopicity is small, at most 1-2%; but for very fine textured soils, at least in the Netherlands Indies, it can rise to above 20%; in Central Europe, except in peat or humus soils, one seldom finds values higher than 8%.

In air which is only partially saturated with water vapor, thus where the relative humidity is less than 100, the soil particles give up part of their hygroscopic water, which later they can again take up from moist air.

The free atmosphere never becomes so dry that the soil particles lose all their hygroscopic moisture; to effect this artificial means are necessary, such as heating to above 100° in a vacuum over P_2O_5. Only in this way can one obtain dry soil, the "dry matter" of the soil.

d. Many Netherlands Indies soils, yes practically all, upon igniting give off additional water; that is the "chemically combined water," which in juvenile soils is but a few percent, but in old, weathered out soils can amount to 14% and more of the dry matter. In questions of water relationships and the soil climate the combined water, because it changes only during a very long time, plays no role of consequence. In a short period the combined water is constant, and is to be considered as a constituent of the solid soil particles.

e. In conclusion, let me add just

one more word about the spaces in the soil--when these spaces are empty, and air is found in them: As long as there is adhering water on the walls, the air will then saturate itself with water vapor; the soil dries out. But if the soil itself is more than dry, that is to say, if the absorbed moisture is less than the total hygroscopicity, and if moist air moves into the cavities, then this air will be able to deposit moisture on the walls and the soil thus becomes moister, although of course not wet. We shall come back again to the question of water vapor movement in the soil; here it is sufficient to point out that in the soil, movement of water can take place not only in the liquid, but also in the gaseous state.

Although qualitatively the above descriptions might be considered adequate for the moment,--there should be added immediately to them the fact that quantitatively changes in all the five forms of water are continually taking place in the soil. So the status quo of the soil water is very uncertain and at any moment is dependent upon the nature and upon the condition of the soil itself, as well as upon the addition and removal of soil moisture,

In this connection, under "nature and condition of the soil" let it be understood that the complex of characteristics which determines the behavior of the soil, with respect to water and water movements, include: structure, pore space, water capacity, perviousness, thus the existence of coarser tubes and finer capillaries; hygroscopicity, plasticity, tendency to shrink and crack, etc. All these characteristics are related most closely to the nature and the size of the separate soil particles, the mutual quantitative relations of these particles, and of what they are composed and how built up.

Hence it is that almost every soil research begins with the investigation of the size and the nature of the separate soil "grains." Such a study, since it is carried out by means of mechanical and hydraulic methods and means is most always called a "mechanical analysis" or "silt analysis," but since the determination of the particles, the grains or granules is at issue, it should perhaps more accurately be called a "granule analysis."

As to the execution and the results of the granule analyses of the soils of the Netherlands Indies they will be repeatedly referred to in other places in this work; here the subject will be gone into only just so far as not to lose sight of the soil water as a factor in the soil climate. In the same way the other summarized physical characteristics will not be dealt with here *in extenso*; it is enough to recall that the "granular composition" depends directly upon the structure of the soil, that is to say, the structural possibilities, structural extremes, structural limits. Within that the structure is however also dependent upon all sorts of other kinds of factors, such as the nature of the particles, mineralogically considered; their form, and the way they settle. Those two main factors: granular composition and structure, together determine the pore space which is filled with water and air, the water capacity in their two forms of capillaries, as well as in the wider tubes. The hygroscopicity, theoretically only a function of magnitude, or rather the minuteness (consequently the surface) of the soil grains, and likely also in addition, depending upon the form and composition of these particles, yet appears in practice to be also dependent upon the structure, the tilth, of the soil; while the plasticity, the characteristics where the swelling, shrinking, cracking and working of the soil are so closely interdependent, presumably depends more especially upon the nature of the smallest soil particles, than upon their size and size ratios.

In brief--the number is legion of the characteristics of a soil, characteristics which have an influence upon the moisture content in its different forms, and on the changes in that content.

* * * * *

Except through internal shiftings, --if one might express it that way--the water content of a soil changes through additions and subtractions. The different ways in which these two phenomena can occur, may be expressed in the general synopsis below:

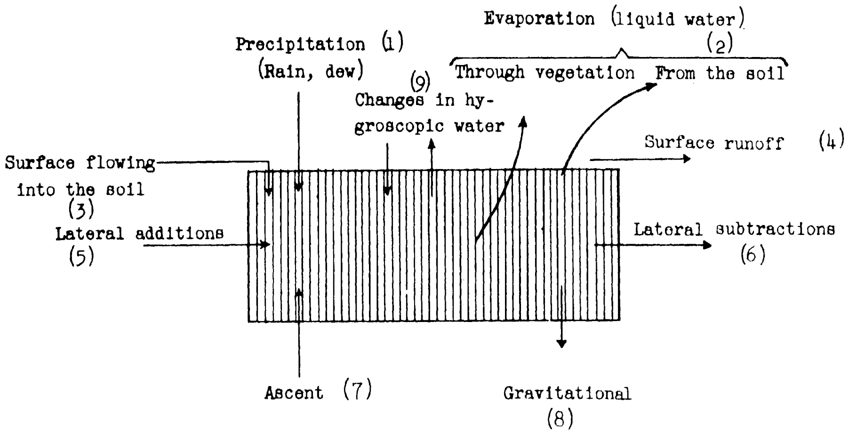

Fig. 5

A single glance at this diagram gives immediately the impression that the water relationships in the soil are more complicated than they are usually represented. This is especially so, if we mentally associate with this diagram what has been stated in the preceding pages about the nature and condition of the soil; we can see that this diagram is somewhat too schematic and too simple. It is too simple to enable us to use the figures for the mean annual rainfall, even though combined with the mean annual temperature of the atmosphere, to draw conclusions regarding the water relationships or the soil climate, whether it concerns the moisture at any definite point, or of a whole region. Yet we have seen this attempted, not only in connection with practical considerations but also in soil science.

In this connection we might mention, for example, the so-called "rain-factor" of Lang[20] which is the quotient $\frac{R}{t}$, wherein R = total annual rainfall, and t = the average temperature during the year. It is clear that this is a purely climatological value, determined with instruments in the atmosphere, without any connection with the soil. Yet Lang uses this factor under certain conditions for soil classification. Thus according to Lang where "otherwise optimal soil forming conditions"[21] prevail with rain factors

above 160	there are formed	"Raw humus soils"
from 160-100	" " "	"Black earths"
100-60	" " "	"Brown earths"
60-40	" " "	"Yellow earths", "red earths", and "laterites"
below 40	" " "	"soils of arid climates"

But if the soil forming conditions are, however, in some feature not completely optimal, then according to Lang quite different soil types can develop, but in each case only inferior, never superior ones. It is as if such soil types had a higher R or a lower t; in other words in the above short table, in going from above downwards one passes from less valuable to more valuable soil types. Thus "nothing is to be expected" of the soils in all places with a RF (rain factor) greater than 200; to this group belong all areas in the Netherlands Indies which, with a temperature of 20° to 25°, have an annual rainfall above 4,000 or 5,000 mm! Whatever may be the value of Lang's rain factor for other places, it is evidently quite useless for the true tropics. If we add that in the Netherlands Indies a number of areas with "redearths" and "yellowearths" are to be pointed out where rain factors vary from about 35 (Asembagoes, East Java)

20. R. Lang, Vers. e. exacten Klassif. d. Böden in Klimat. u. geol. Hins., Int. Mitt. Bodenk. 5 (1915), p. 312.
21. Cf.: Handbuch der Bodenlehre III, p. 8.

to above 400 (on the slopes of the Slamat and in the Preanger), while "blackearths" occur in places with rain factors varying from 30 (near Waingapoe on Soemba) to 90 (Modjo, Soerakarta), it is obvious that Lang's rain factor is of no significance at all for the Netherlands Indies. Others also, among them Stremme,[22] are opposed to the system Lang established.

Alfred Meyer proposed[23] a quite different system: the quotient $\frac{N}{S}$, where N = the precipitation, and S = the saturation deficit. This is also a meteorological quantity or if one wishes, a climatic factor, but in any case quite independent of all soil characteristics. And this is the main objection which from our point of view can be raised against all such systems. But, if we can start out from the soil itself, and can then correlate soil characteristics with certain climatic conditions, then of course the relationships would be entirely different.

* * * * *

In any case we should begin by turning back to the schematic diagram shown above of the soil and the additions and subtractions of water, and let us consider in detail some of these water movements as they occur in Netherlands Indies soils:

1. The amount of water that soaks into the soil depends, in the first place, upon the quantity of precipitation, which in the Netherlands Indies consists of rain and dew.[24] The latter is often observed in the topics but nothing is to be found in the literature concerning the actual amounts.[25] In temperate regions[26] maxima of about 0.2 mm. dew falling per hour occur. For the tropics the maxima will certainly not be less; for during a cloudless night of approximately 12 hours maxima of more than 2 mm. dew per night have been observed. If there are but 100 days in the year with the formation of this amount of dew, then for the year this amounts to the important quantity of 200 mm. We naturally hope that within a short time we shall be able to show actual figures instead of such approximations as these. The order of magnitude of the estimates certainly ought to motivate experimental investigations, especially since Braak[27] clearly speaks of "the heavy dew formation in the tropics."

As to what extent the dew forming on the surface of the ground penetrates the soil, there are no data.

On the other hand the data relating to rainfall are very numerous, particularly because regular measurements can be made so readily with the different forms of rain gauges.

* * * * *

Rainfall in the Netherlands Indies

Since in the Netherlands Indies the rainfall varies so widely, from place to place, within short distances, the necessity was early seen of establishing a very close net of rainfall observation stations both in order to satisfy the needs of science and in order to meet practical requirements. Regarding rainfall a number of publications[28] have been issued by the Royal Magnetic and Meteorological Observatory and one might say

22. H. Stremme, Zur Kenntnis d. Bodentypen, Geol. Rdsch., 7 (1917), p. 330.

23. Alfr. Meyer, Ueber e. Zus. zw. Klima u. Boden in Europa. Chem. d. Erde, 2 (1926), p. 209. Cf.: Handbuch der Bodenlehre III, p. 10.

24. We suppose, we can never hope to find snow elsewhere than on highest peaks of New Guinea; so that it can here remain out of consideration. Hail occurs more often, compare Braak Het Klimaat v. Ned.-Indië-Batavia 1924, I, p. 442-449. Quantitatively the hail is recorded with the rain.

25. Braak, l. c., p. 394.

26. Handbuch der Bodenlehre III, p. 208-220.

27. Braak, l. c., p. 394.

28. Regenwaarn. in Ned.-Indië., I (1879--to date). Idem: Maandgemiddelden; Java en Mad., (1922--to date), Buitengew, (1920--to date). Idem: Jaargemiddelden over langere tijdvakken. Observations, made at Royal Magnetic and Meteorological Observatory, I (1866--to date). Observations, made at secondary stations on N. E. I., I (1911--to date).

that there are few lands in the world where there are available such extensive and well-arranged rainfall statistics. From those statistics I propose to include here what is useful for our purpose:

a. The average total annual rainfall records are made up from observations, which running to and through 1928 cover a period of time from at least 5 years for some stations to as much as 50 years for a few stations. The annual average rainfall varies between about 0.5 m. (Paloe, Celebes) and about 7 m. (Tombo, Central Java). The records for some of the stations during some years fall outside these limits; annual totals as low as 400 mm. and as high as about 8,000 mm. have been recorded. Meanwhile when grouping the published[29] annual figures of more than 3,300 stations it appears that the values approximating the extremes mentioned seldom occur (see Table 28).

From this Table 28 it appears that by far the greatest number (91%) of the annual figures fall between 1 and 4 m. of rainfall and almost a half (45%) between 2 and 3 m. of rain. The several great regions of the Archipelago, however,

Table 28

AVERAGE ANNUAL RAINFALL IN THE NETHERLANDS EAST INDIES

Average annual rainfall	0.5-1	1-2	2-3	3-4	4-5	5-6	above 6
	Meters per year						
No. of stations	20	858	1494	667	210	35	10
No. in % of the whole	1	26	45	20	6.5	1	0.5

diverge considerably in this respect (see Table 29).

From this Table 29 it can be concluded that Java as a whole has just as high an annual rainfall as is the average for the whole Archipelago: that the Islands of Sumatra, Banka, Billiton, Borneo, the Molukkas and New Guinea which lie more nearly on the equator, on the average receive more, while Celebes and especially the smaller Soenda Islands, and all islands lying farther east, receive materially less. If we divide Java in two, then the rainfall of Western Java is of about the same magnitude as the islands of high rainfall, while Eastern Java with a lower rainfall is more

Table 29

AVERAGE ANNUAL RAINFALL IN REPRESENTATIVE REGIONS OF THE NETHERLANDS EAST INDIES

Parts of the Archipelago	Percentage of the rainfall stations with an annual average of--						
	0-1 m.	1-2 m.	2-3 m.	3-4 m.	4-5 m.	5-6 m.	more than 6 m.
Banka and Billiton......	---	4	73	23	---	---	---
Borneo..................	---	6.5	52	38.5	3	---	---
Sumatra.................	---	17	42.5	29	9	2.5	----
Molukkas and N. Guinea..	---	18	64	15	1.5	1.5	---
Java....................	---	27	46	19	7	1	---
Celebes.................	2.5	33	51	12	1.5	---	---
Smaller Soenda Islands, Timor and others......	21.5	64	13	1.5		---	---
West Java...............	---	10	39	34.5	13	2	1
East Java...............	---	38	49.5	10	2.5	---	---
Total for the Netherlands Indies..........	1	26	45	20	6.5	1	0.5%

29. J. Boerema, Regenval in Ned.-Indië, Verh. Kon. Magn. Meteor. Obs. Batavia No. 24 (1931).

like Celebes and the Smaller Soenda Islands.

All this is however very general and states very little about the soil climate. Boorema's treatise[30] can shed more light on this. From this work we can see how the rain falls, how it is distributed through the year, that is, in some places it is divided regularly, some falling in each month, while in others all the rain is concentrated within a few months while the rest of the year receives practically nothing. A number of examples can show this better than can a description (see Table 30):

2. While it is easy to measure the rainfall with a rain gauge, it is very troublesome to go further into the questions as to what becomes of the water; how much of it runs off over the surface. It is extraordinarily difficult to measure the evaporation from a soil surface by direct measurements. The quantity depends upon a number of factors, differing from place to place, and in time from hour to hour, from minute to minute. It does not seem advisable to go into the matter of evaporation in too much detail. The question really is: what is the average evaporation of a tract not measured by sq. cm. but by hectares or sq. km.; and likewise not from hour to hour, but per day, per month, or per year. Assuming that the evaporation is proportionate to the (horizontal) evaporating surface, (which applies to water surfaces and flat land, but does not apply when one has to do with rough broken land and steep slopes), --it suffices to express the evaporation in only one dimension, the vertical; hence it is stated in mm. depth of water, as in the case of rainfall.

Table 30

VARIATIONS IN RAINFALL DISTRIBUTION IN REPRESENTATIVE REGIONS OF THE NETHERLANDS EAST INDIES

Place	Average Annual Rainfall	Lowest Average Figure for a Month	Place	Average Annual Rainfall	Average Number of months under 65 mm.
Windesi (New Guinea)..........	3382 mm.	239 mm.	Bandjaran (Moeriah)...........	3422	4
Fakfak (New Guinea)...........	3145	202	Makassar (Celebes)............	2850	4
Liroeng (Celebes).............	2817	187	Soenggominassa (Celebes).......	2552	5
Sorong (New Guinea)...........	2762	163	Kajoemas (East Java)..........	2526	5
Bojan Poelau Boeloe (Riouw)....	2398	150	Badjawa (Flores)..............	2176	5
Balikpapan (Borneo)...........	2176	133	Sf. Soekoredjo (Pasoeroean)....	2094	6
Boewool (Celebes).............	1989	120	Widarapajoeng (Besoeki)........	1501	7
Batoepanggal (Borneo).........	1949	111	Soë (Timor)...................	1450	6
Kalossi (Celebes).............	1700	100	Koepang (Timor)...............	1443	7
Kotaradja (Atjeh).............	1638	91	Reo (Flores)..................	1307	8

If one compares the left and right halves of this Table 30, there will be found corresponding annual rainfall figures, and yet--what differences! On New Guinea at Windesi no month has less than 239 mm. so it is always wet there; and on the N. W. slope of the Moeriah (Bandjaran) the annual fall is still higher, but there is a dry season of at least 4 months, during which the soil can thoroughly dry out. As to why the left hand column of Table 30 ceases with a minimum of about 90 to 100 mm., and in the right hand column are counted the months under 65 mm., deserves closer elucidation. Both are related to the water economy in the soil; further on we will discuss them in more detail.

* * * * *

Meteorological and climatological stations consider evaporation exclusively as an atmospheric phenomenon; and they measure it with conventional fixed evaporation meters, which are flat open vessels, usually of brass; the evaporating surface is pure water, of a temperature approximately that of the atmosphere. Thus, for

30. J. Boerema, Typen van den regenval in Ned.-Indië. Verh. Kon. Magn. Meteor. Obs. Batavia, No. 18.

example, the following figures (Table 31) have been determined:[31]

These annual figures lie between about 500 and 1,300 mm. of evaporation. For the various months of the year, especially in the eastern corner of Java, these values may strongly diverge, as shown in Table 32.

The official evaporation meters thus give monthly figures lying approximately between 30 and 150 mm.

From the water reservoir of Wadoek Soembersono at Lengkong (Kediri) an evaporation, as measured by the Irrigation Service, for the years 1914-1923 averaged 4.5 mm. per day (about 1,650 mm. per year). The lowest daily figure is 3.8 mm. for February (that is 114 mm. for the month); the highest daily rate 5.5 mm. was in September (or 165 mm. for the month). This shows clearly the influence of the dryness of the air during the east monsoon. These figures are of the same order of magnitude as those of the Wild evaporimeters, etc., of the

Table 31

EVAPORATION OF WATER IN JAVA

Places in Java	Evaporation	
	Annual Average per Day:	Average per Year: (Previous column x 365)
	mm.	mm.
Batavia....................	1.5	550
Buitenzorg.................	2.5	910
Patjet (growing garden)....	0.9	330
" (open meadow).......	1.6	580
Kawa Tjiwideui.............	1.4	510
Bandoeng...................	2.8	1020
Pekalongan.................	1.7	690
Soerabaia..................	3.2	1170
Pasoeroean.................	3.6	1310
Tosari.....................	2.0	730
Djember....................	3.1	1130

Table 32

VARIATIONS IN EVAPORATION IN DIFFERENT PARTS OF JAVA

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Batavia Western Java	36	36	38	38	39	40	48	57	60	57	48	45
Soerabaia Eastern Java	61	60	61	66	80	85	102	135	156	144	120	69

31. C. Braak, Klimaat v. Ned.-Indië, I, No. 6, (Batavia, 1924), p. 385.

meteorological stations; and in general agreement with the following data from other countries:[32]

Annual evaporation from a pond at Madras, India (very hot and dry!) 2,300 mm.
Annual evaporation from a water reservoir at Bombay, India (hot and dry!) 1,930 mm.
Annual evaporation from lakes (which ones are not stated) 1,600 mm.
Annual evaporation from a water reservoir in SW Africa[33] (very dry!) 2,200 mm.

Now what will the evaporation from the soil be? There is the a priori tendency to suppose that the evaporation from a soil surface which is not submerged will be less than that from an open water surface. And in fact, as soon as a soaking wet soil surface, begins to dry off, the evaporation decreases more and more.[34] But under certain conditions, such as bright sunshine after much rain,--at the outset though perhaps only for a very short period--the evaporation from a soil surface can be noticeably greater than from a corresponding water surface. And then, as already indicated above, besides a number of other factors the vegetation should be reckoned with. The vegetation affects evaporation in two ways: on one hand a part of the rainfall, remaining hanging on the leaves and branches, evaporates before it reaches the ground; and on the other hand a more or less important portion of the moisture is taken up out of the soil and evaporates through the leaves (transpiration). It is thus very difficult to find an adequate basis for comparisons and so for the conclusions resulting from them. Consequently we will consider different methods of approach to the question and note certain facts.

At Buitenzorg[35] observations were made during 1907 and the following years, using cylinders about 0.5 m. high and 0.5 m. in diameter filled with soil, wherein the evaporation was indirectly determined through the direct measurement of the rainfall, the run-off from the surface, and the percolation: $V = R (A + D)$. Evaporation = Rainfall - (Runoff + Percolate). As a result of these measurements it appeared that from an annual rainfall of approximately 4,200 mm. at Buitenzorg about 1,100 mm. ran off from the surface of the bare soil, almost 1,900 mm. soaked into the soil and percolated down through, so that about 1,200 mm. evaporated.

One is instantly struck by the fact that this figure of 1,200 mm. is of the same order of magnitude as those values met with in the above recorded series of observations on water surfaces. Should soil and water differ so little in this respect?

A Wild evaporimeter--not mounted in the way desired by the meteorologists, in the shade in or under the meteorological shelter, but placed close beside the soil cylinders, exposed to the wind and sunshine and only shielded against the rain,--gave quite different values. Arranged according to the evaporation figures, some of the results are found in Table 33 below (see page 54).

* * * * *

The freely exposed evaporimeter certainly did show a notably higher evaporation rate than the official instrument which was installed in the shade under the shelter; the exposed evaporimeter also gave much higher figures than did the soil cylinders. Yet four months of highest evaporation from the soil when the soil was wettest closely followed the evaporation from the free water surface (92-97% of the latter); these were exactly the months with the highest number of rainy days: 17 to 21: the rest of the months had but 7 to 14.

It is to be noted how the evaporation increases with the rainfall. That may seem strange at first sight, but it must be remembered:--that 1st, in order to be able

32. V. Hann, J., Lehrb. d. Meteorol. 3e dr., p. 218. Ref. in Braak, l. c., p. 391.
33. F. Herrmann, Die wasserwirtsch. Grundl. d. Subtropen, m. besond. Berücksicht. S. W. Afrikas, Tropenpfl., 35 (1932), p. 196.
34. E. C. J. Mohr, Ueber Verdunstung v. Wasser-u. Bodenoberfl., Bull. d. Dépt. d'Agr. Buitenzorg., No. XXIX (1909), p. 1-12.
35. E. C. J. Mohr, Kl. bijdr. t. beoord. v/h waterhuish. vraagst., Teysmannia, 20 (1909), p. 151-166.

Table 33

WATER EVAPORATION FROM AN EVAPORIMETER AND FROM SOIL

	Year 1908 Month	Rainfall R in mm.	Evaporation: VM of the evaporimeter	Vb of the soil	Vb in % of Vm	Vb in % of R
Wet Season	Oct.	625	151 mm.	139 mm.	92 %	22 %
	Jan.	528	141	136	97	26
	April	576	140	134	96	24
	Feb.	373	108	103	95	28
	Mar.	189	147	102	69	54
	Dec.	242	149	95	64	39
	Nov.	371	121	94	78	25
Dry Season	Aug.	272	147	92	63	34
	May	242	145	91	63	38
	July	261	135	86	64	33
	June	392	145	85	59	22
	Sept.	135	152	81	53	60
	Total	4205 mm.	1681 mm.	1238 mm.	ave. 74 %	ave. 29 %

to evaporate, water must be present; in the comparatively dry month of September, there also stands next to a maximum Vm of 152 mm. a minimum Vb of 81 mm., because for days the soil remained dry and there was no moisture to evaporate. And 2nd--heavy rains generally follow bright mornings, so that whenever water is still present from the previous day, it also easily evaporates.

From the observations above-mentoned (Table 33),--supplemented by similar observations of a half year preceding and several subsequent years, it appears that the relations drawn in the rough for the conditions of the experiment hold good; after graphing the data it was possible to deduce that the evaporation can be represented very approximately as a linear function of the rainfall:

$$V = C + f \cdot R$$

in which the constant C comes to about 60 and the factor f to about 1/8th. This of course applies only to the observations from the Buitenzorg experiment, that is, for the cylinders of the above recorded measurements and for the Buitenzorg soil (= brownish yellow, very pervious lixivium); to generalize from such results is hardly permissible, but it is obviously not easy to decide how values may be obtained that are suitable for even a limited portion of the Buitenzorg landscape. But what is one to do if there are no data relating to such a region? Then the only possible thing to do, under explicit premises of the speculative nature and uncertainty of the conclusions, is to try to work out something.

According to the above formula then, the Buitenzorg terrain has a climate with a rainfall of about 68 mm. per month. The evaporation is of about the same magnitude as the rainfall. If the rainfall is less than 68--say 60 to 65 mm., then the point is reached at which the runoff and percolating water both become practically zero, and all the rainwater again evaporates. But if the rainfall is greater than 68, a surplus can penetrate into the soil, and during heavy showers a portion runs off over the surface.

But whether this estimate will also apply to other places and kinds of soils, is again a pertinent question. In cases where there is vegetation, which intercepts a part of the rain by its foliage, so that it never reaches the soil, and also

withdraws considerable water from the soil, which is transpired. Thus water may not penetrate deep into the soil and the figure of 68 mm certainly will have to be raised. Moreover, Buitzenborg has a relatively moist climate; in drier localities even in the rainy season, one would not expect that there would often be a month like that of June 1908 when of 392 mm. of rain only 85 mm. evaporated. Therefore--as long as no experimental data are available--for safety's sake it appears desirable to increase the limit to 90 to 100 mm. of water evaporated per month. We may assume with reasonable certainty that any surplus rainfall over this amount soaks down into the soil.

We thus come to the certainly not unreasonable, but yet inadequately established supposition, that with R (rainfall) less than 60 to 65 mm. per month in the tropics a climate may be called a dry (arid) one, while with R more than 90 to 100 mm. the climate may be called wet (humid).

This is why in Table 30 on page 51 in the left hand side examples were chosen, where for all the months the rainfall remains above 100 mm. and only in one case as low as 90 mm.; on the contrary in the right hand side are examples with approximately the same annual rainfall, but at the same time with at least four months of less than 65 mm. rain. In the localities on the left then, it may be accepted that during the whole year the downward movement of water takes place, while in the localities on the right, during a number of months water movement pauses or even reverses and soil moisture moves upward.

* * * * *

If we compare this result with what others have said about the question, then it appears that on some points there is a close agreement. It is true that those who drew up classifications of climate were geographers or climatologists, so that they have established their boundaries in accordance with the vegetation and the rivers rather than with the soil. But even when considering the tropics, their results are worthy of mention.

In 1910 A. Penck[36] differentiated humid and arid climates according to the runoff of the rivers. If these flow regularly, then the climate of the drainage basin was considered to be humid; if not, then the basin was believed to be periodically or constantly arid. For the rainfall boundary, at which the rivers cease to flow, Penck assumed about 1,100 mm. per year for Central America. In the Netherlands Indies however annual figures are unsatisfactory.

For the equatorial climate without a dry period, E. de Martonne[37] believed an annual rainfall of at least 1,500 mm. to be necessary. Months with less rain in mm. than double the temperature in °C, he calls "practically dry"; for a "desert climate" at least 8 such months were held necessary. For places in the Netherlands Indies with a temperature of 25 to 27°C this would mean a limit of 50 to 54 mm. rainfall per month.

Köppen[38] has worked out other relationships. Although he had formerly (1901) placed at least 2 months of "dry period" with less than 6 rainy days per month as a limit between "always moist rain forest climate" and "savanna climate"--a limit, under which all central and East Java would fall into the savanna climate;--later (1918) he arrived at the following position:

Tropical rain climates (A)
have with an average annual temperature of about 25°C to about 20°C--an average annual rainfall of at least 700 mm.-600 mm.

They are further to be divided into:

(Af): continuously moist; having even in the least rainy months at least 60 mm. rain.
(Am): monsoon rain climates, with moderate dry periods.
(As) and (Aw) = (Ad): periodically dry savanna climates, with an annual

36. A. Penck, Vers. e. Klimaklassific. a. physiogeogr. Grundl., Sitz. ber. Pr. Acad. Wiss., Phys. Math. Kl. (1910), p. 236-246. Ref. in Handbuch der Bodenlehre II, p. 28-29.
37. E. de Martonne, Traité de Géographie physique (Paris, 1909), p. 205-225.
38. W. Köppen, Klassific. d. Klimate n. Temp. Niederschlag u. Jahres lauf., Pet. Mitt. (1916), p. 197-203.

rainfall of 2,500--2,000--1,500--1,000 mm.
the month poorest in rain has at the most 0--20--40--60 mm.

Dry climates (B) are subdivided into:

(BS) steppe climates, having--
with an average annual temperature of 25°C, 20°C, 15°C, 10°C.
an annual rainfall smaller than 700--600--500--400 mm.

(BW) desert climate, with rainfall maxima equal to half that of the steppe maxima. (BW) does not occur in the Netherlands Indies; for there are no annual rainfall figures under 350 mm. Even (BS) occurs very seldom (Paloe, Celebes, has 546 mm. as the 20 year average). Köppen differentiated (As) and (Aw), according to whether the dryness falls in the summer (s) or in the winter (w). For the Netherlands Indies, if considering the soil, (As) and (Aw) had better be combined under (Ad).

If this subdivision is applied to the Indies, then all three (Af), (Am) and (Ad) are found extensively, but (Af) occupies by far the greatest portion. It may be noted that Köppen also arrives at the limit of 60 mm. for (Af); below that he considers a month "dry." Even so, from the pedological standpoint the Köppen system is not satisfactory because the soil is not considered one of the important criteria for the subdivision: instead it is the rain gauge, with, in addition, a glance at the character of the flora. In this book, we will not ignore the connection between the soil and the flora; far from it! But we also know that plants, at least very many kinds, exhibit a very great adaptive power, so that great care must be used when determining the limits of the flora on the soil. Moreover a disadvantage of the Köppen system is that it divides what really do not lie far apart, and joins together, groups which actually strongly differ.

On the supposition that the intention of Köppen was that the criterium for (Ad) against (Am), given above, may be drawn in a graph as a slanting straight line of $\frac{2500}{0}$ to $\frac{1000}{60}$, the 4 following Netherlands Indian rainfall stations get the following Köppen designations for their climate[39] (see Table 34, page 57).

All four stations exhibit 4-month averages each under 100 mm. and 8 months between 100 and 200 mm. It is true there are differences but they are small, the general character being similar. The vegetation will certainly not react to those small differences; yet Singkarah comes under the continuously moist rain forest climate. That is unsatisfactory.

If we now compare three sets of three stations each, each falling under one climatic group (see Table 35, page 57), then only with difficulty could one maintain that each of these three groups has a single character, exhibits one floral type, and has one and the same influence upon the soil. Not only that within each group the annual figures differ very greatly but according to de Martonne (see above) Gorontalo has one equally dry month; Larantoeka however has six, and Takalar, in spite of a much higher total, still has five! For the soil this statement certainly has its significance.

The three places under the (Af) climate also differ markedly; Singkarah has not a single month above 176 mm., Bojan not a single one below 150 and not one above 256, while Indaroeng has not one under 349 mm. Although one might now say that the soil at all of those three places is kept continuously wet yet certainly at Indaroeng the runoff, and the erosion, for example, will have a much more violent character than at Singkarah.

In short--Köppen's system does not suffice for the Indies, and it is certainly desirable to search for a better one to replace it.

Let us start with the question: how can one use rainfall figures to determine the possible occurrence and intensity of a dry period in the soil? The answer must agree as closely as possible with reality and also be one which can be carried out in practice. Therefore, after various attempts, which yielded less satisfactory results, it has been decided to start out

39. Rainfall figures taken from Boerema, Verh. Kon. Magn. Meteor. Obs. No. 24 (1931). That the choice has been made of stations from the other islands and not from Java, is entirely arbitrary. Farther on use enough will be made of the observation on Java.

Table 34

KÖPPEN VALUES FOR NETHERLANDS EAST INDIES STATIONS

No. of the station	47a	363	354	352
Place	Singkarah (Sumatra)	Donggala (Celebes)	Limboto (Celebes)	Gorontalo (Celebes)
January........	176	193	145	112
February.......	94	155	112	122
March..........	130	158	127	111
April..........	156	107	143	126
May............	102	100	139	109
June...........	67	128	105	115
July...........	64	96	78	91
August.........	91	87	58	75
September......	116	69	49	46
October........	143	59	70	65
November.......	125	111	141	108
December.......	176	141	154	135
Year...........	1440	1404	1321	1215
Köppen Climatic Classification	A.f.	A.m.	A.m.	A.d.

Table 35

No. of the station	352	468	426	362	331	425	47a	164	43
Place	Gorontalo Cel.	Larantoeka Flores	Takalar Cel.	Tinombo Cel.	Talisse Cel.	Limboeng Cel.	Singkarah Sum. W. K.	Bojan P. Bo-eloe, Riouw	Indaroeng Sum. W. K.
January......	112	249	574	56	421	678	176	232	508
February.....	122	241	360	63	296	408	94	152	382
March........	111	187	304	93	308	288	130	175	541
April........	126	102	98	158	225	102	156	241	548
May..........	109	51	86	182	158	67	102	210	473
June.........	115	24	36	141	114	44	67	168	361
July.........	91	13	16	154	95	15	64	150	349
August.......	75	8	4	117	55	7	91	177	440
September....	46	6	14	117	64	21	116	186	567
October......	65	40	46	59	117	71	143	229	665
November.....	108	110	166	75	236	192	125	256	742
December.....	135	183	445	67	322	569	176	222	618
Year.........	1215	1214	2149	1282	2411	2462	1440	2398	6194
Climate......	A.d.			A.m.			A.f.		

with the following system:

1. Both on account of a limit of from 60 to 65 mm. found in the writer's experiments and because Köppen assumes the same limit of 60 mm. for the "continuous moist," while de Martonne also pretty closely approaches that limit with his differentiation of "moist" and "dry" months, I have taken 60 mm. rain as the limit, above which a month is considered as more or less moist, and beneath which a month is considered as more or less dry.

2. It does, however, make a great difference whether for a definite station there occur but one or two such dry months, or seven or eight. The number of months is thus of great importance.

3. It is also of importance whether the dry months are preceded and followed by moderately moist months (with R between 60 and 100 mm.) or with quite wet months (with R greater than 100 mm.).

In the first case the first dry month is easily counted with those that are fully "dry"; in the latter there is obtained a residual effect from the preceding very wet season so that for the soil and the vegetation in many places the "dry time" really begins to take effect later. Similarly the significance of the drought will be relieved earlier by a following month with much rain, than by a month with only moderate rains (with R between 60 and 100 mm.). For example: 3 dry months with 9 wet ones, that is a quite sharp, but not long, dry period, preceded and followed by heavy rains. But 3 dry months with 5 wet ones, means 4 transitional months. Then if 2 transitional months precede the dry period and two follow it, the dry period is felt much more intensely in the soil and by the vegetation.

On the basis of these considerations the stations from which the monthly rainfall figures (up to and including 1928) were available, were grouped according to their number of "dry" and "wet" months; while the number of "moist" months (between 60 and 100 mm.) automatically follows from that: v = 12 - (dr + n) moist = 12 - (dry + wet) (see Table 36).

Only one station: Paloe on Celebes, with 11 months under 60 mm. and one month between 60 and 100 falls entirely outside of this Table 36.

Now it is obvious that we cannot show separately on a map all the 45 groups which occur; they must be combined into larger groups. If we take into

Table 36

		Number of "wet" months (each with more than 100 mm.)										
		2	3	4	5	6	7	8	9	10	11	12
Number of "dry" months (each with less than 60 mm. rainfall)	0	-	-	-	-	3	8	33	155	202	235	750
	1	-	-	3	1	2	15	71	142	48	8	
	2	-	-	1	1	2	33	145	133	11		
	3	-	-	2	7	30	237	298	98			
	4	-	1	-	9	78	215	67				
	5	-	-	18	38	51	56					
	6	2	1	20	20	8						
	7	-	-	23	2							
	8	-	2	3								

Ia and Ib

II

III

Groups

IV

consideration what was said above under No. 3, then in the scheme standing above the "drought" will increase not only from above downwards, but also from the right toward the left, forming five, or really six, larger groups, as indicated by the broken lines in this scheme.

Group I. The continuously wet or at least moist stations, where (on the average) the rainfall of no single month falls below 60 mm. There are very many of these stations and there are big differences between them. For example: there are those in which the rainfall in no single month goes above 200 mm., and others with no single month below 300 mm. Next to stations where the wettest and the driest months show but little difference, there are others where the monsoons make themselves felt stronger or weaker through notable differences in rainfall. Even so all stations of this group have the following characteristic in common: practically speaking in all months of the year there will be found to be a surplus of rain above evaporation, and this is important with respect to the soil and the vegetation. If now we again divide the stations where the minimum month does not fall below 100 mm., this gives us the places with the continuously "wet" climate, and hence wet soil. These areas are distinctly separated from the places where one or more (at the most 6) months occur which are only "moist" (with 60 to 100 mm.). We shall name those 2 groups Ia and Ib.

In the second place one might make still another division based on gradual differences for example, thus:

I_α--stations where no single month of the year has an average of more than 150 or 200 mm., and

I_β--stations, where no single month of the year has an average under 200 or 300 mm.

Particularly with an eye upon such questions as sheet erosion such a division should certainly be of significance, but it would also be applicable to groups II-V. And there is the further objection--apart from the fact that attention would be diverted from water economy towards erosion--that too great a number of groups would be obtained. Therefore we should keep the latter division "in mind" and maintain the above-named separation only in Ia and Ib.

Group II. The places in the Netherlands Indies where only one "dry" month is observed, would be considered as having a weak dry period. And quite weak, for in those regions the soil really does not dry out, or at most only the uppermost surface soil on bare land. Where 9 or 10 "wet" months follow 2 "dry" ones as in groups (2-9) and (2-10), there is really a sharp dry period, but given the prelude and the postlude, droughts of long duration certainly do not occur: therefore these 2 groups are added to II.

Group III. A notably often-occurring type with maxima of (3-8), (3-7) and (4-7) is very widely distributed, especially on Java. Here there is observed a marked dry season, during which the soil can dry out quite thoroughly to a considerable depth; consequently during a part of the year the evaporation exceeds the additions of moisture.

Group IV. In this group that phenomenon of a dry season comes more clearly into the foreground. It is self evident that the groups (4-3) and (4-8) do not belong in one larger group, but (4-3) goes better along with (6-6) in IV, and (4-8) better with III.

Group V. Finally a few places with a long and fierce drought are best placed together into a separate group.

On this basis the adjacent map of Java and Madoera was drawn. Since outside Java the number of stations with an adequate number of years of observations is still too small, it is not yet possible to prepare a similar map for the entire Netherlands Indies.

It must be admitted that in a careful study of the map the grouping gives the impression of arbitrariness in the drawing of the boundaries. But in view of the practical problems in map drawing and reproduction this criticism can seldom be avoided and certainly not, whenever, as

here, there are differences which continually shade one into the other. Yet as will clearly appear in the subsequent portions of this book the limits chosen are not as arbitrary as they may appear to be.

Although a corresponding map of the other islands than Java cannot be presented, something may be said as to about how such a map would look.

The greater part of Sumatra falls into the groups Ia-Ib and II; group II especially in the southeast to approximately a line from Palembang to Bengkoelen, and then on the Batak highlands; III almost only in North Atjeh.

The Riouw Archipelago, Banka, Billiton, and Borneo fall entirely into groups Ia and Ib, except that behind Bandjarmasin lies a small patch of II, showing the approach of the influence of the dry east monsoon. The rest of the soil on those islands does not dry out as it does in East Java.

Celebes exhibits an alternating rainy climate, and thus causes the map to have a colorful design as in the case of central and East Java. Celebes also lies about equally distant from Australia.

The small Soenda Islands are similar to East Java; except that from west to east the groups Ia and Ib rapidly disappear. Except for a few spots, group II disappears in the same way; group V, on the contrary, is more prevalent.

Of the Molukkas and New Guinea the data are still extremely scarce; it looks, however as if groups Ia, Ib and especially II are the dominant ones, although there are a few stations (for example Merauke lying more to the south) which go into III and IV. But climatologically the northern half of New Guinea belongs entirely with Borneo and Sumatra.

We shall have to restrict ourselves here to these main impressions.

* * * * *

In the preceding discussion, the limit of 60 mm. rainfall was rigidly held to as the minimum below which arid conditions in the soil would certainly appear, and above which the soil climate would be more humid. However, it is not as simple as that.

In the first place the temperature, (in the Netherlands Indies the elevation) has an influence; the higher one goes, the cooler it is, which in turn also reduces the evaporation. On the other hand, a stronger radiation in the higher tracts will heat the soil surface intensively and in this way further the evaporation. However, a great deal depends upon the saturation deficit of the air, a quantity which is locally very variable. On the outer slopes of the mountains the saturation deficit in rising currents of air will of course become smaller (cloud formation) and then the evaporation will diminish; but whenever a descending Föhn wind sets in upon the slopes or upon high plains, then the winds at the higher elevations may already be dry. The Föhn is not so drying, however, as is the "Koembang" wind in the low plains of Cheribon, or the "bohorok" on Sumatra's East Coast. In short--a general formula cannot be so simply stated. Besides there are a few high mountain stations, such as, for example on the Idjen Plateau, where definitely "dry" months occur.

It is much more important, however, to consider, in connection with the possibility of evaporation, what happens to the rain water on and in the soil. From this it will appear that very different soil climates can occur under the same air climate. In this connection let us first turn back again to the diagram on page 48.

* * * * *

2b. The withdrawal of moisture from the soil as affected by vegetation, both through modification of the evaporation rate at the surface as well as through roots taking moisture from deeper layers and consequently drying out the deeper soil, will be treated at greater length under other headings; here it may be sufficient to record a few important facts.

Better than theoretical considerations, we may call attention to the results of an investigation[40] which has been carried

40. In: Yves Henry, Terres rouges et terres noires basaltiques d'Indochine (Hanoi, 1931), p. 174.


JAVA
JAVA
INDISCHE OCEAAN
STRAAT MADOERA
INDISCHE OCEAAN

out in French Indo-China, a tropical country. Y. Henry has recorded some observations by F. Auriol on two plots of the Giaray experiment station; one plot of red, uncultivated soil, bare of all vegetation; the other plot of red soil covered with heavy, second-growth forest. Each month the plots were sampled, and in the samples the water content was determined. The results, recorded in graphs, are here stated in figures. The figures for the rainfall are also given (see Table 37):

Table 37

SOIL MOISTURE UNDER BARE AND FORESTED LAND

		1929				1930							
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
	layer	%	%	%	%	%	%	%	%	%	%	%	%
Bare land	0-15 c.m.	26.4	24.5	27.5	20.3	20.6	19.4	16.7	23.9	25.9	27.6	24.5	27.5
	0-30 c.m.	27.2	26.1	28.2	22.6	22.7	22.3	20.3	24.9	27.3	28.6	26.1	28.0
	30-60 c.m.	29.3	28.7	29.4	26.2	25.7	23.9	22.6	22.7	29.0	30.0	28.9	29.4
	100-130 c.m.	29.6	30.0	29.8	27.4	26.0	25.6	26.0	25.4	30.4	30.5	30.3	30.6
Forested land	0-30 c.m.	28.5	27.0	27.1	22.7	22.8	21.7	21.2	25.2	27.3	27.5	28.3	29.1
	30-60 c.m.	27.6	26.4	25.6	23.4	22.6	21.9	21.4	22.2	26.9	24.1	28.3	28.6
	100-130 c.m.	27.6	26.3	25.4	24.4	23.7	22.0	21.6	21.4	26.3	24.0	27.2	28.2
Rainfall in mm.[1]		425	195	147	28	16	32	13	80	321	229	336	364

1. (In Henry's paper is printed c.m.--I believe this is a misprint. E. C. J. M.)

In this two things stand out: 1st--that under the forest the different layers of the soil vary much less in moisture content than those of the bare plot; 2nd--that the subsoil of the forest soil shows a smaller water content than that of the deforested soil. The author explains this in the following way:[41] 1st--considerable rain is intercepted by the leaves and evaporates, hence less water reaches the soil. The 2nd--and main reason is that the vegetation takes an important portion of its water from the deeper layers of the soil.

This explanation is admittedly quite correct; but it is probably not yet complete. For we know that elsewhere[42] Henry recorded that the bare soil has a clay content of about 62%, while the soil under the forest yielded values 52--52--38% for this. In this connection we might call attention to what N. Beumée--Nieuwland[43] writes:

> "If in soils of that kind with a high content of fine constituents there are influences at work which do not favor a crumb structure or even work against it, then the rain water penetrating into the soil can take away from the soil existing in the crumb structure a part of that clay. In deeper layers the narrowing capillaries or the presence of flocculating agents precipitate this clay..... The crumb structure of the surface layer is in part destroyed by the tropical rains beating upon unprotected soils;.... crumbs which are present become beaten to bits, washed away in the rain water, and are carried into the pores of the soil. Proofs of this are to be found in the results of the investigations of Pitsch (1884), Wollny (1889),

41. L. c., p. 174.
42. L. c., p. 171.
43. Meded. Proefst. Boschw., 8 (1922), p. 39.

Fesca (1873), Ramann (1890), and others. For the Indies J. Beumée (1919)[44] calls attention to this."

It is thus quite conceivable that in Tonkin on bare soils an addition of clay has taken place by which the water capacity of the upper layers was increased, and thus a higher water content was found.

Reverting to the outcome of the investigation in French Indochina it must be pointed out that in many localities of central Europe, upon comparison of adjoining plots of the same sort of soil, partly occupied by forest, partly bare or at most carrying some thin grass, a clear difference in ground water position was established[45]; in short, let the conclusion be stated thus: forests and, in general, all kinds of intensive vegetative cover lower the ground water level. As to what this signified relative to interplanting of cover crops between permanent crops--both in the case of too high ground water, and in the case of a scarcity of moisture,--will be considered elsewhere.

How much water is evaporated by East Indian plants such as grass, cogon (*Imperata cylindrica*),[46] talahib (*Saccharum spontaneum*), perennially-green leafy forest, teak forest, and teak forest periodically dropping their leaves under minimal, optimum, and maximal water conditions, are questions which remain to be answered.

In general, however, vegetation also facilitates the penetration of rain water into the soil; to some extent this compensates for the extra loss; sometimes the penetration far exceeds the transpiration losses, especially upon slightly sloping land. Vegetation also, however, may greatly facilitate the flowing off of the rain water and thus decrease the penetration; for example, in pine forests on slopes where the soil is covered with fallen needles. If we also keep in mind that such a forest of course also sucks up water out of the soil and causes it to evaporate, and that all forests hold up a part of the rain in the crowns of the trees, then the water content of the soil is decreased in a three-fold manner. As a rule,--and one can admit this without any hesitation,--luxuriant vegetation, such as the forests of the East Indies, reduces the fluctuations in moisture content of the soil, extracts the moisture out of the subsoil, and promotes moisture movement from the surface soil toward the subsoil.

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(3) Flowing onto the soil over the surface (see Fig. 5, page 48) and

(4) the flowing off over the surface have significance in nature only in connection with the gradient of the land, thus in connection with slope and the occurrence of ridges and knolls on the one hand, and of valleys and depressions or sinks on the other hand.

Whether or not there will be any water movement over the surface depends, in addition to the slope of the land, upon two or really three factors: (1) the intensity of the rainfall; (2) the possibility of the soil (i.e., the surface layer) soaking up the water, and (3) the power to conduct this water downward to the lower layers of soil (i.e., the permeability). If the last-named factors are large, as for example is the case of dunes, then the intensity of the rain may be great, and the slope steep, yet no water will flow off over the surface; all is at once soaked up and is carried downward.

If, however, the power of soaking up the water and/or the permeability is small, then even with modest showers of rain there are likely to be considerable amounts of water moving over the surface.

So in nature under one atmospheric climate, various situations may obtain, depending upon the slope and the nature of the soil. Yet there are extreme cases which apply to almost all soil conditions: a shower of rain can be so heavy that

44. O. Pitsch, Theorie der Bodenbearbeitung (1884); Wollny, Forsch. a./d. Geb. Agr. Physik XII, p. 33; Fesca, Journ. f. Landw. XXI (1873), p. 460; E. Ramann, Die Waldstreu u. i. Bedeut. f. Boden u. Wald (1890); J. Beumée, Tectona XII (1919), p. 146.

45. See: Handbuch der Bodenlehre IX, p. 382-385; A. Bühler, Der Waldbau (Stuttgart, 1918), I, p. 446 en volg.; E. Ramann, Forstl. Bodenk. u. Standortsl., (Berlin, 1893), p. 309; Bodenkunde (Berlin, 1911), p. 450.

46. See footnote 45.

almost no conceivable soil can completely take it all up as fast as it falls, and this water then flows practically everywhere over the surface of the soil; on the other hand, a shower can be so light, or fall with such a slight intensity, that any and all kinds of soil can absorb it, and then water never flows over the surface. The cases where a surface flow of water onto or off from a definite tract takes place, or does not take place, occur more often than one would theoretically expect; because (1) the extremes of perviousness and of imperviousness are not so widely intermingled, and (2) great expanses of land frequently have a very uniform soil type, or at least a not so extremely differing perviousness.

In the chapter on "Irrigation" we shall refer again to water flowing artificially onto and off from the land.

* * * * *

(5) Lateral additions of water to
and

(6) lateral loss of water from the soil are generally of little significance. Movements of water in both these directions are mainly dependent upon the perviousness of the soil material, and since the forces which give rise to the replacing of the water have, as a rule, only very small horizontal components, any appreciable lateral movement of water takes place only in pervious soils. This movement takes place mostly in soil close to the ground water table or below the ground water level.

Small differences in this respect are sometimes clearly perceptible in the vegetation. For example, when a road-cut runs through a tuff formation which is a complex of layers of earth of varying degrees of perviousness; then we can see very clearly, from horizontal strips of mosses, little ferns and certain grasses, which layers exhibit lateral water movement and which do not.

Also beside water channels, rivers, or canals with a water level higher than the surrounding land, one can observe in protracted dry times a better growth of vegetation the nearer one approaches natural or artificial dikes along the channel. However, this phenomenon occurs only in case of pervious dike material (rich in sand or coarse volcanic ash).

(7) Ascent and

(8) percolation bring us directly to still another important phenomenon in the soil, namely the ground water and the ground water level. If the ground water level is many meters deep, it has little influence on surface soil moisture. On the other hand if the ground water level stands close to or at the soil surface, one would seldom consider the water as running through.

Let us consider first the case of a water table very deep below the surface. As far as the upper portions of the soil are concerned the water table is practically nonexistent. If the soil is uniform and pervious, then gravity will be able to fully manifest itself. The rain water penetrates downward from the surface, fills the capillaries, saturates the surface soil, and in case there is much water available, it penetrates farther and farther. And if the air under it can but find a way out somewhere,[47] the water acts as a sucker that is, as it sinks farther it sucks air from above into the cracks and capillaries freed from water, while beneath new capillaries and cracks, constantly fill up so that finally the ground water is reached and fed. This process continues until this descending water stands in equilibrium with the ground water. Apart from the hygroscopic moisture, there is then in the soil only adhering water, water in the angles, and water remaining in the fine capillaries, besides the water in the capillaries in connection with the ground water.

One realizes instantly that perviousness is of great significance for the progress of this process. The less pervious the soil is the more slowly the process proceeds, at a certain limit it will practically come to a standstill. Indeed heavy clay and loam soils frequently

47. If the air cannot find a way out below, then its pressure is at once raised. If thus in a shower on flat land the surface is cut off by water, little or no water can penetrate deeply.

occur in the Netherlands Indies, with practically zero perviousness; in such soils not only the flowing through ceases (8), but also the ascent (7), and the lateral water movements (5) and (6), mentioned above. But can we then also do away with (1) and (3), that is, the penetration of water and (2) the evaporation? By no means, but they proceed very differently! We will return to this presently.

First let us now consider only the case of a pervious soil with a high ground water level, just below the surface of the soil. Whenever a heavy shower falls, then soon the penetrating water will unit with ground water and raise the ground water level; if the ground water can escape laterally, then the case is not very different from that first mentioned. But if it cannot get away, the water rises closer to or even stands on the surface, the soil becomes over-saturated with water and is without air. Only through evaporation can the soil reappear again above the water, for example in the next dry monsoon.

Under what conditions is there a definite capillary ascent of water? Immediately after the rain ceases and the dry period begins? By no means everywhere; only in certain circumstances. In a soil, homogeneous of texture and structure, the ascending water comes from the ground water, and only will rise in proportion to the rate of water removal from the higher capillaries. In soils which are particularly suited for drawing up water, the greatest actually observed rise is from 2 to 2.5 m. To move that distance the water requires about a month. If the ground water level lies 2.5 m. or more below the level from which the water is taken up, then ascent is practically out of the question. Isn't it true that those soils which have the highest capacity for drawing up water always consist for the greater part of coarse silt of 20 to 50 mu? When you come across soils with a larger proportion of finer grains, for example clay of 1 to 2 mu., then the theoretical height to which water can ascend is almost 50 m. but the time that is needed for even one meter rise is about two years.[48] However by that time the entire "dry season," even though it continue for 8 months, is long past.

The removal of water may occur: a) through evaporation; or b) through the plant roots. For a) it is essential that the capillary passages connected with the ground water continue to or close to the suraface of the soil. If one is dealing with soil that draws up water very strongly, then the ground water must certainly stand not deeper than about 2.5 m., if one is to notice on the surface anything of the ascent. In more sandy types of soil, this distance must be much smaller. And in the heavier loam and clay soils there is no need to have any illusions that through capillary rise the water lost from the surface soil during heavy droughts can be replaced.

For b), that is to say water loss via the plant roots, the ground water level can, from the nature of the case, lie deeper than for a). The roots of many plants go down 1 to 2 m. deep, those of many trees as much as 8 m. or more. For example, even if the ground water level is 10 m. below the surface it is possible that forest on this land, even in the driest time does not suffer for lack of water. On the other hand the water table may stand at 5 m., and if the forest is chopped down in order to make the land available for permanent crops, the roots of these crop plants cannot go deeper than 2 m., and hence cannot survive the dry period; capillary ascent does not bring the water nearer than about 3 meters below the surface.

Now there is still another complication which should not be neglected! If water rises by capillarity, the ground water must at the same time be replenished from below or from one side; if that does not occur, then there would develop a vacuum somewhere beneath and that cannot be; hence under such condition the capillary rise cannot occur.[49] The roots of the plants must then exist with whatever capillary water there is present; if they need more it will be necessary for the roots to grow to it. For that matter, they must do that in all the heavier soils, wherein water movement in general, and this also includes ascent, takes place so extremely

48. Cf: the extensive calculations and considerations of F. Zunker in: Handbuch der Bodenlehre VI, p. 104-114.

49. Cf: Zunker, l. c., p. 111.

slowly that for practical purposes there is none at all.

* * * * *

(9) Of the diagram (Fig. 5, page 88) of water relationships there still remains to be considered the variation in content of hygroscopic water. Whenever the relative humidity of the atmospheric air drops appreciably below 100 per cent, the soil although already quite dry, will still lose moisture, namely the hygroscopic moisture. Especially when heated by radiation from the sun the soil temperature rises to far above that of the atmosphere. For example, when with an air temperature of 30°C and a relative humidity (RH) of 40 per cent, the actual water vapor tension is 0.4 x 31.5 = 12.6 mm.; if in addition to this the surface of the soil is warmed to say 45°C, then the R.H. is $\frac{12.6}{71.4}$ = 17.7 per cent for the immediate proximity of the soil particles; with such a "drought" these particles will lose much of their hygroscopic water. There are soils in the Netherlands Indies whose hygroscopicity exceeds 20 per cent, so with the dryness mentioned these lose in the form of water vapor more than 10 per cent of their weight of water. If during the following night dew falls, the loss of hygroscopic moisture is forthwith made up. But even if no dew falls, then cooling off through radiation from the soil is already sufficient for the soil particles on the surface to again take up hygroscopic moisture from the atmosphere, even though this moisture be imperceptible to the eye.

(10) Regarding water movements in the soil in the form of water vapor we could also mention a number of important things but space forbids their consideration.[50]

* * * * *

Now if we survey what has been said under headings (1) to (9), then it appears that all factors which contribute to the water relationships are liable to continual variation. The result is an equally variable amount of water in the soil. In order to be able to say something about it, the conception "water capacity" has been introduced, but at the same time the necessity was realized of defining that conception. A controversy has gone on for many years regarding the paraphrasing of those conditions; even today this controversy has not been straightened out. But this much is now quite clear, that some types of soil have much higher capacities than others and the same weight, or same volume, of one soil can take up much more water than can another.

If by exposure to rain, for example water is added to a "dry" soil--which may already contain considerable hygroscopic water--then first the hygroscopicity is raised to its maximum, and then the capillary pores and spaces are filled until the maximum water capacity is reached. Then the soil is "wet." Under continuously "humid conditions" the water content is continually close to this maximum water capacity; while under "arid conditions" the water capacity lies continually near the "dry" point, close to the so-called hygroscopicity, or even below it.

Now if nothing else happened, the matter would be quite simple. It is, for example, quite so for a coarse sandy soil. The water mentioned under 1)--is of no significance; since the water mentioned under 2)--is what the plants live on in a sandy soil.

But in heavy soils, such as clay, other factors prevail. If the clay particles behaved exactly as sand grains, that is to say, if in the presence of much water they remained the same as they were without water, then with a heavy clay soil one would have this case: the clay is dry, hard impervious; rain falls on it; the surface becomes moistened, the rest of the water cannot penetrate and runs off; in short--a behaviour as if only a stone layer were there. But the conditions are really otherwise: as will be clear from these observations:

50. Whoever is desirious of making a closer study, is referred to Handbuch der Bodenlehre VI, p. 198-209.

If 1 dm^3 of dry sand weighs 1,600 grams, and the specific weight is 2.67, then the volume of the sand grains is $\frac{1,600}{2.67}$ = 600 cm, hence the volume of the pores is 400 cc. Now if the sand takes up 400 gm. water in those pores, then the volume of the wet sand is still 1 dm^3 and and the maximum water capacity is $\frac{400}{1,600}$ = 25% (calculated according to weight).

Let us contrast this with a clay, such as often occurs in the Netherlands Indies. At the maximum water capacity 42 gm. of the wet clay would have a volume of 27 cm^3. When thoroughly dried out and in addition kneaded and weakly pressed (only with the hand) the final weight would be 24 grams. Thus the water loss would be 18 gm. (75 per cent). But those 24 gm. occupy a space of only $\frac{24}{2.67}$ = 9 cm^3 + 1 cm^3 (10%) air space = 10 cm^3. With the taking up of water these 10 cm^3 swell to 27 cm^3, thus to 270% of their dry volume.

It is of importance to keep clearly in view what this signifies in nature, a swelling of the soil upon taking up water from say 3 to 8, or a shrinking from 8 to 3 upon drying out! Various conditions contribute to prevent such extremes--from being observed to this degree. In the first place many soils are not really clay soils but loam soils, and these have a lower capacity for swelling and shrinking. Secondly, soils in nature do not so frequently become saturated to their maximum water capacity, and thereafter are but seldom strongly dried out down to their minimum moisture content; a little moisture almost always remains behind. Thirdly, however, in nature gravity acts on great quantities of wet, plastic clay so that the whole mass sinks or rises vertically; this we men do not so quickly observe. If we do not use suitable instruments and do not have at our disposal bench marks anchored deep in the unchanging subsoil, a rising or sinking of even 1 to 2 ft. of a large level field escapes us. A great deal of the cubic swelling or shrinking really does take place in a vertical direction, and is more or less imperceptible to our eye. Fourthly together with the shrinking an additional phenomenon, cracking, comes in as a factor, sometimes as single big cracks in not too fine grained loam soils; sometimes, with very colloidal clay soils, as an endless cracking and granulation of the soil down to very fine cubes, to sharp-angled "sand," even to a fine "sand" which may blow about in the wind.

It is a good thing to keep in mind that it is just the heaviest soils, those richest in colloidal clay, that are the most plastic and impervious when moist and wet, and which upon drying out, crack, break down, and granulate. If such a soil did not crack, then after a long drought it could hardly become moistened afresh. Actually however, it readily becomes moist again, because the land is broken up by wide, sometimes meters-deep crevices and fissures, as well as minute cracks. Whenever the first rains fall the points of application for moistening are legion and the thorough moistening of this material, practically impervious to water, need take but months or weeks, in certain cases only a few days, in place of years. Similarly, the water loss at first takes place from the surface, and increases as the smaller and larger cracks originate, thus exposing new surfaces for evaporation. Drying out in this way may continue for months, though it extends to only 1 or 2 foot depths.

So there is a great and principal difference with respect to the manner in which the water economy regulates itself in pervious and impervious soils. The difference is something like that between the human traffic in a great railway station and in a concert hall; in the one case the traffic is flowing through, in the other the hall fills and then again empties.

For the impervious soil types this signifies that when once they are fully saturated by a quantity of water, which is, for example, 300 mm. rain, any further rain that falls cannot be absorbed. So it makes no difference whether in the rainy season 500 mm. or 2,000 mm. falls, the surplus runs off over the surface. What the consequences of this are for the final weathering stage will be further considered in the chapter on "Weathering."

Meanwhile it is desirable to emphasize once more that from the point of view of soil science, it is not enough to say: with a monthly rainfall of 100 mm. or more a downward movement of water will occur,

and with a monthly rainfall of less than 60 mm. the reverse will occur. Such a statement applies only to pervious soil material; and as far as upward movement is concerned, is further limited by those restrictions which have been spoken of above under "ascent." But for impervious soil material descending and ascending movements of water as such remain practically out of consideration; in these soil types one is concerned with other processes.

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3. AIR IN THE SOIL

Besides solid constituents and soil water, there is more or less soil air. If a definite volume of soil be taken as unity, ($V_s + V_w + V_l = 1$), the volume of the solid parts (V_s), calculated over a certain time is quite constant. Also that of water plus air is constant, as $V_w + V_l = 1 - V_s$. From this it follows that V_l is largest when the soil is as dry as possible (V_w is at a minimum); and that V_l becomes the smallest when the soil is saturated with water, (V_w is at a maximum).

From the many figures which are given in the literature[51] we record here only that V_s seldom goes below 0.26 or above 0.60 so that $V_w + V_l$ then varies between 0.40 and 0.74. By way of exception in very dry soil V_l can be more than 3/4 of the whole volume, in dried out peat for example 0.84, but as a rule it does not exceed 0.40 to 0.55. In soil saturated with water, the water never occupies the entire space $V_w + V_l$, which is called the pore space or the porosity, but always allows a little air to remain over; in other words the maximum water capacity, calculated volumetrically, remains always less than the pore space. That difference is sometimes quite considerable, viz. 0.15, but it can also be very small, to almost 0. In the latter case almost all of the air is out. A soil is however hardly ever saturated to the maximum, so that the minimum of V_l, approaching 0, very seldom occurs in nature; as a rule the air content shifts between 0.05 and 0.30 or 5% to 30% of the pore space.

If the water content is approximately equal to the "liquid limit" (more about this later), that is, a certain water capacity somewhat lower than the maximum, then $V_l = 1 - V_s - Vl$ = the space taken up by the air (for example, a few hours after a long-continued, fairly-heavy rain). This is sometimes called the air capacity. This quantity is of great importance for vegetation; for various European cultivated crops Kopecky[52] determined the optimum to be between 5 and 20%.

In the Netherlans Indies Kerbosch and Spruyt[53] came to the conclusion that the air capacity of Cinchona (quinine) soils varied between 16 and 31%, and has an optimum at about 27%.

From data of Vriens and Tijmstra,[54] wherein are mentioned figures relating to the porosity and also to the water capacity of many Deli soils, although air capacity is not mentioned, the figures may be calculated as follows (see Table 38):

Table 38

AIR CAPACITY OF "DELI SOILS"
(Including the Residency of Sumatra's East Coast)

In % of the total volume	Minimum	Maximum	Approximate limits
Porosity.........	48.9	87.3	50 to 75%
Water capacity...	33.9	55.3	35 to 55%
Air capacity.....	8.5	39.2	10 to 40%

Most of the figures lie between 14 and 27%; as regards the order of magnitude, they are in good agreement with the above-mentioned results relating to the

51. See for example in the Handbuch der Bodenlehre VI, p. 268-342 the part by F. Gieseke, Das Verhalten d. Bod. g. Luft,--where will be found an extensive bibliography and tables.

52. J. Kopecky, D. physik. Eig. d. Bod., Intern. Mitt. Bodenk., 4, (1914), p. 147. Ref.: Handbuch der Bodenlehre VI, p. 281.

53. M. Kerbosch en C. Spruit P. Pzn.: Beoord. v. kinagronden, enz., Cinchona VI, (1929), p. 34-111.

54. J. G. C. Vriens en S. Tijmstra Bzn., Deligronden. Numerous papers in Meded. Deliproefst. Dl. II to VI.

Cinchona soils and with the values of European soils.

In an extended consideration of soil research[55] P. W. E. Vageler discussed soil air relationships; there he clearly points out the fact that up to that time (1928) in the Netherlands Indies still inadequate attention was given to the quantities of air in the soil. Actually with respect to tea and rubber soils, but especially relating to still undisturbed soil types, nothing is to be found in the Netherlands Indies literature relating to air relationships.

Interesting therefore are the results obtained in Pusa, British India; they are the more worthy of being noted here in that they have been so seldom incorporated in European literature. W. H. Harrison and P. A. Subramania Aiyer studied the gases of paddy (wet rice) fields[56]; their work was later rounded out by J. W. Leather.[57] The latter in diferent determinations[58] found first of all that in the dry season, thus not under submerged conditions, the water content in the Pusa soil to about 1 m. depth varied from 16 to 6% by volume and the corresponding air volume between 30 and 45%; in the following rainy season the water content increased from 25 to 33%, while the air (gas) content decreased to between 30 and 15% by volume. Only in a deeper layer (1.25 m.) were found lower figures namely from 10% to as low as 4% by volume; these are, however, still rather high amounts of air.

* * * * *

The remarkable thing about the British Indian researches which were carried out at 30°C, (hence under tropical conditions) is, however, that that air is sometimes no longer "air," but is an entirely different mixture of gases; this brings us to the question of the composition of the soil atmosphere.

The European investigations[59] limit themselves mainly to the constituents nitrogen, oxygen, and carbon dioxide, and since the former two vary much less than the carbon dioxide, most researches deal with the variations in the CO_2 content. Unfortunately because of errors in the method of determination some of these investigations are quite valueless. The soil actually possesses all kinds of solid constituents which absorb all sorts of gases; and the water also absorbs gases and holds them in solution; these absorbed gases should not be included in a statement relating to the soil atmosphere. However, if we drive off the gas by heating the soil and consider that gas as the "soil air," the results cannot be accurate.

In general it has been found, however, that the ratio $N_2:O_2$, amounting to about 78:21 in the atmosphere, diverges but little in the uppermost layers of the soil. At 15 cm. depth the O_2 content may fall occasionally to 19%, and at 70 cm. depth to 13%, yet it always remains quite considerable.

The CO_2 content in the free atmosphere is about 0.03% by volume, while close to the soil, for example at 2 cm. above it, with an absence of wind, it is usually 2 to 3 times as much:[60] if there is quite a breeze, then no difference exists. In forest, especially in the mornings after a quiet night, even at a greater height, for example 1 m. above the soil surface, the CO_2 content is still double or more the content outside the forest. It is a pity that figures for the tropics are still lacking.

In the soil, that is, in the uppermost horizons to about 30 cm. (1 ft.) depth, amounts of a higher order have, however, been found; in a quartz sand soil only 0.05 - 0.1 per cent by volume, in a loam 0.07 - 0.3%, and in peat soil 0.4 to more than 1.0 per cent by volume. At 1 m.

55. Archief v. d. Theecult. in Ned.-Indië, I, No. 2 (1928), p. 87-89.
56. W. H. Harrison and P. A. Subramania Aiyer, The gases of Swamp Rice Soils, Mem. Dept. Agr. India (Pusa), III, No. 3, IV, No. 1 and No. 4, V, No. 1 (1913-1916).
57. J. Walter Leather, Soil Gases, Mem. Dept. Agr. India (Pusa), IV, No. 3 (1915).
58. Leather, l. c., p. 99.
59. Cf. Giesecke, l. c., p. 282-302.
60. Cf. Giesecke, l. c., p. 256-257.

depth there is as much as 0.4 - 2. and even 5 per cent by volume. In garden soil mixed with stall manure the content of CO_2 may rise to 7 per cent by volume.

But whenever a soil stands under water, quite different figures are obtained. Thus Harrison and Aiyer[61] found in the water free soil air from rice (paddy) fields:

Nitrogen	N_2	between	75	and	11%	by	volume
Oxygen	O_2	"	2.8	"	0	"	"
Carbon dioxide	CO_2	"	2	"	20	"	"
Methane	CH_4	"	17	"	73	"	"
Hydrogen	H_2	"	0	"	2.2	"	"

Here we see that the oxygen almost entirely disappears, sometimes even the nitrogen also, while their places are taken by carbon dioxide and more especially by methane and also hydrogen. In other determinations hydrogen increased to even more than 11 per cent!

Leather refined the methods of investigation still more by determining, in addition to the nitrogen, also the argon, which in the atmosphere is approximately 1/80th of the nitrogen. In this way he could see in the ratio N:A whether the so-called "nitrogen" of the earlier determinations (actually N + A) remained present as such and inactive, or whether through the microflora N was added to it or was given off. He found[62] that actually the ratio, which in normal surface soil is about 75 to 81.5, under rice field conditions can run up to 92 to 98; this is only to be explained by admitting the evolution of nitrogen through the action of bacteria.

Remarkable also is Leather's discovery that in the immediate neighborhood of the roots of Crotolaria juncea, indigo and corn (maize), growing in "normal" soils, the ratios of the constituents of the soil atmosphere[63] diverge so strongly from the figures found in Europe:

Temperature:	Nitrogen	73 -85%	by	volume
about 30° C	Oxygen	2.2-13.8%	"	"
Air content:	Carbon	4.8-17.0	"	"
5.5-25.0%	dioxide			
by volume	Methane	none		
	Hydrogen	0.0-1.4%	"	"
	Argon	0.9-1.1	"	"
	N/A	76 -83	"	"

Even though the sampling was done at 30 cm. (1 foot) depth or less, and even though there is always some oxygen everywhere in such dry soil the low content of oxygen is striking. However, close by the roots the carbon dioxide content is quite high. Methane was never found here, but hydrogen quite regularly which is quite remarkable. It seems unlikely that the roots "exhale" hydrogen; this gas is probably produced by microorganisms. But then likewise the microorganisms may have produced CO_2 and it becomes uncertain, in how far the roots have played a part in the CO_2 production. Leather rightly insists here upon a closer investigation relating to these important biological questions.

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It was worked out by Zunker,[64] that the perviousness of soil for water and the speed of diffusion for the soil gases run completely parallel, if one chooses suitable units. From that it follows that a highly pervious soil also exhibits a rapid gas diffusion, and the deviations of the soil atmosphere from the composition of the free atmosphere above it can be but small. Large differences occur only where diffusion is at a minimum or is lacking, that is, in impervious soil and also in the layers beneath it, although they are, in themselves, quite pervious.

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61. L. c., III, 3, p. 69-70.
62. L. c., p. 110-114.
63. L. c., p. 115.
64. F. Zunker in Handbuch der Bodenlehre VI, p. 166-173.

Finally a peculiar phenomenon should be pointed out which may sometimes have important effects upon the soil water and the soil gas; that is, the adsorption of all sorts of gases upon the solid soil particles.[65]

From what was said about hydroscopicity (page 65) we already know about the adsorption of water vapor. In just the same way as water vapor is held by such soil constituents as kaolin, humus and especially iron hydroxide, these substances also hold fast upon their surfaces great quantities of other gases, particularly carbon dioxide, ammonia and even nitrogen. Consequently soils rich in iron also absorb very considerable quantities of these gases, and there have been found some soils upon which could be fixed more than 4 gr. NH_3 gas and 4 to 7 gr. CO_2 per 100 gr. of soil.

Since the results of different investigators still do not agree very well more will not be said here about this. Since no investigations in this direction have been made in the tropics, suffice it to say that absorption of gas must not be neglected, and that this absorption can give rise to misunderstandings. For example, in Vageler's modern and, in many respects, very valuable little book about tropical soil science we find[66] the idea that "the earlier opinion that the striking red and yellow soils of the tropics should be poor in humus, is entirely wrong; contents of 10% and more organic matter are not at all uncommon." Whatever particular method one follows to determine that organic matter, it is never[67] determined directly, but it is calculated from the quantity of carbon dioxide obtained from the sample by burning it in one way or another. But supposing that little true organic matter is present, yet much carbon dioxide may be absorbed on the abundant iron oxyhydrate of the red, reddish brown and yellow soils, then according to the usual methods of analyses the carbon dioxide will be driven off weighed and calculated back as humus. How great is this error? A conclusive experimental answer must be given to this question before we can agree to Vageler's very positive statements.

Another question is, just how much do such absorbed gases, especially carbon dioxide, affect the degree of acidity? One thinks he has noticed that if iron oxide hydrate adsorbs pure nitrogen, nitrate is thereby formed; a phenomenon which reminds us of some technical processes of "nitrogen fixation from the air"; thereupon one may say that there is nothing new under the sun. In short--various important problems are connected with such adsorption of gases; this is however not the place to go farther into this subject; the soil climate is already quite complicated enough.

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65. F. Giesecke, l. c., p. 315-341.
66. P. Vageler, "An introduction to tropical soils," (translated by H. Greene), (London, 1933), pp. 7, 74 and 76, 85 and 86, etc.
67. Only the direct separation and weighing of "matière noire" is an exception to this.

Chapter III

THE PROCESSES OF WEATHERING AND SOIL FORMATION

Starting out on the basis of

1. the parent materials considered in the first chapter, and

2. the soil climate discussed in the second chapter, we must now go into the question of how, under the influence of all the factors which make up the soil climate, or stated more broadly: how all the factors which originate in or are effective in the soil, alter the parent material. So now we must go into a study of

3. the processes of weathering and soil formation.

We have learned to know the parent material as rocks, and these as made up of complexes of minerals. In the following discussion of weathering, those forces which attack and change the minerals and rocks but which do not act at the surface of the earth, or are not influenced by "the weather," are not up for discussion here. These endogenous forces (such as gas and steam exhalations, warm springs, and other phenomena, which have their origin deep in the interior of the earth), will not be considered, though we approach very close to them and even come into contact with them where, for example, the soil comes into contact with river water which comes from craters. It is rather the so-called exogenous phenomena which we will now consider.

* * * * *

There are two paths open for the study of those exogenous weathering phenomena.

The first would consider the rocks as a whole, follow their total changes, and in conclusion would study the kinds of soil as a whole which originate from those rocks. In commencing a study along this line one would restrict himself to a more or less minute description of what could be observed; in a later stage one would proceed to all sorts of analyses and so arrive at more amplified conclusions. In the past, and still today, for many, this is the only useful path.

The second path proceeds from the idea that rocks are complexes of minerals, that these minerals, which upon weathering under the action of the weathering influences, behave differently, so that one has to consider the minerals first separately, and then go into the changes which each can undergo by itself. Also the intermediate and end products which they will give in the course of their weathering must be considered, so that it will be possible to draw an adequate picture of how the rocks weather, as well as how the soil is formed.

It may be doubted whether it is possible to choose between these two paths, that is to say, whether the one path excludes the other. More likely it should be considered that each one supplements the other, and that either one will throw some light upon the other. This is especially necessary, since a priori the second path promises more insight into what goes on in weathering and soil formation, but on the other hand for the second path a presupposition is made which is superfluous for the first. This supposition is that with reference to the weathering forces the minerals of a rock behave independently of each other; that each one goes its own way, provided that the environment in so far as it takes part in the weathering, remains but the same. In an absolute sense this theoretically established premise will occur very seldom; it is only intended to express that one mineral will not influence the other directly, for example, in its reacting with water or air. Practically, however this comes down to indirect influences via an environment such as water, where the

diverse minerals react with it, and owing to this the surroundings are changed, as in a definite solution. This new environment can now be changed through the influence of mineral A in such a manner that it becomes different in its reacting with mineral B, thus an indirect influence of the weathering of one mineral upon another is easily imagined. But with the knowledge of physical chemistry and of colloid chemistry those mutual influences, can, to a great extent, be reduced to known laws; these facilitate the construction of the composite weathering picture and places it on a known and firm foundation.

It stands to reason, and can therefore be demonstrated in the process of development of a number of sciences that, in comparison with the first, the second path wins in importance and interest. Haven't people always done that whenever it was possible, splitting a very involved and complex problem into a number of questions of simpler nature? As a rule they have even done this in spite of the fact that they might anticipate that in so doing, the amount of work involved would really be more. However in passing final judgment upon the results of such a partial investigation as here intended, we must never lose sight of the fact that even though the individual parts are placed together these do not necessarily give the whole picture. Just as a human being is still something more than the complex of the morphological, physiological, and chemical subordinate parts and characteristics which can be observed; just as even an atom is probably something more than merely a crowd of mutually related protons and electrons; in just the same way also the "living soil," considered in a broad way, is still something more than a complex of constituents, whose characteristics and behavior one can, to a certain degree, study and determine. This inspires one to caution and modesty, but should not encourage despair and inaction!

The attempt, which will be made in the following pages to guide the reader in a consideration of the weathering of the soil along the above-mentioned "second path," is still weak and incomplete. I gladly admit that the results appear to me as meagre, but, nevertheless, by no means discouraging.

* * * * *

1. About the weathering of the separate minerals, which are of importance in soil formation:

It is customary to differentiate; mechanical or physical weathering and chemical weathering. The former will be discussed below in No. 1 of Chapter 4; while at this point the chemical weathering will be considered.

By this term is meant the weathering in which the minerals are attacked, so much so that even the lattice itself is often times completely broken up. Of the constituents liberated, some are carried away in solution, others are separated out again in new combinations which form in that place or elsewhere. Chemical agents coming from outside, in the liquid or in the gaseous form; water, carbon dioxide, oxygen, organic materials dissolved or not dissolved in water and still a few others to be mentioned later, play a part in this. Of all these, water is the foremost; for chemical weathering cannot occur at all in the absence of water.

* * * * *

Water in nature is never pure water; there is always something dissolved in it. Upon what is dissolved in the water determines how the weathering of the minerals will proceed. Consequently it is necessary to consider first, what constituents may be dissolved in the water, and how they determine its character as a weathering agent.

The purest water is no doubt rain water, especially in the tropics, particularly after the first water in the beginning of a heavy shower has purified the air. For example, if from a shower of 80 mm. or more, the rain, after the first 20 mm., be separately collected, the amount of dissolved substances therein is very small. In the first 20 minutes solid particles are washed out of the atmosphere, just as the nitrates and ammonia. The higher temperature of the tropics causes the rain water to possess less dissolved gases than in the temperate zones.

It has long been taken for granted that the acids especially those dissolved in the water: carbonic acid, nitric acid

(coming from electrical discharges in the atmosphere), sulfuric acid (coming from the oxidation of pyrites and other sulfur ores in the rocks), and organic acids (humus acids) were the ones which caused chemical weathering; not until much later was it realized that water, even without anything else dissolved in it, intensively attacks a number of minerals. It is not necessary here to consider all possible cases and combinations.[1] We shall here limit ourselves to the action of the most important liquid weathering materials, such as are found in the Netherlands Indies, upon the minerals which are included in the diagram (Fig. 1, page 7).

With respect to these liquids, we should note the following facts: It is true that all are for the most part water; all are dilute solutions, of salts, acids, or bases; but besides these there are, however, in many cases, colloidal sols of varying nature. Consequently those liquids may have widely divergent degrees of acidity; on the acid side the pH may vary between 7 and lower than 3, and on the alkaline side between 7 and higher than 9. It is obvious that that degree of acidity has a strong influence upon the course of the weathering of the minerals; therefore, the effect of reaction will be taken up more in detail.

From pure water of pH 7 we may here differentiate; Water containing carbon dioxide. If the content of free carbon dioxide is but small, then the pH is also only a little lower than 7; but if the content is higher, then the pH falls, to reach with saturation of the water the extreme of about 3.85, say 4.

If such water is in contact with the mineral calcium carbonate, then there is formed water containing calcium bicarbonate, wherein the alkaline influence of the lime predominates, so that the pH reaches values of from 7.5 to 8.5. In nature with calcium carbonate plus free carbon dioxide, the pH actually varies between 7.5 and 4.5.

Sea water exhibits pH figures from 7.8 to 8.4; close to the mouths of large rivers somewhat lower figures naturally prevail, but yet seldom below 7.5. Thus, sea water always has an alkaline reaction.

Also the water which has come in contact with fresh basic volcanic ash has an alkaline reaction; as to why this is will be explained later. Its pH can rise to as much as 7.5 or 8. This liquid might here be called sodium carbonate-containing water, although it contains besides Na still other bases such as Ca, Mg, and K.

Humous water, as a rule brown colored ("ajer hitam"), is more or less acid, just as is the "bog water" in Europe; in the Netherlands Indies the pH is often lower than in Europe, that is, lying between 5 and 3, sometimes even below 3.

Yet there are some artesian wells which also give brown water containing humus, which because of a high content of soda is alkaline (pH about 8).

The most acid water is found in the runoff from crater plains and crater lakes. In such crater water free sulfuric acid and hydrochloric acid give pH figures of from 4 to as low as 0.5.

We can thus draw up the following series (see Table 39, page 74).

A few examples from the Netherlands Indies might elucidate the above series; they are mostly taken from the Annual Reports, 1928-1931, of the Experiment Station for Water Purification at Manggarai, Batavia.

It was recorded that at the following places for the provision of drinking water there was available only "humous brown water" with a

pH of 4.4 at Pontianak
" " 4.3 at Balikpapan
" " 4.3 at Bagan Si Api Api (East Coast of Sumatra)
" " 3.7 at Selatpandjang (Bengkalis).

All four places are far from all young volcanic activity, and located in low tracts where definite bog formations occur.

Samples from tropical bogs, collected by J. van Baren in the Netherlands Indies, showed a pH of 2.8 to 4.8.[2]

On well water from the following

1. Whoever wishes to go deeper into the general questions of weathering should consult, among others, the following: F. W. Clarke, The data of Geochemistry, U. S. Geol. Survey, Bull. 695 (1920), 4th ed., Ch. XII where also much important literature is cited. See also: K. Blanck, Chemische Verwitterung, Handbuch der Bodenlehre II (1929), p. 191-224, who cites much later literature.

2. W. A. J. Oosting, Landbouw, IV (1928-1929), p. 240.

Table 39

REACTION OF NATURAL WATERS

No.	1	2	3	4	5	6a	6b	7
Nature of the water	Crater water	Humous water	Water containing CO_2	Pure water (rain water)	Water containing lime and CO_2	Water containing Soda		Sea Water
						Without Humus	With Humus	
pH	0.5-4	3-5	4-6.5	6.5-7	7-8.5	7-8.5	7-8	about 8

places the following acidities were determined:

pH of 5.5 at Pangkal Pinang (Banka)--granite and sandstone
" " 5.7 at Muntok (Banka)--granite and sandstone
" " 5.7 at Manggar (Billiton)--granite and sandstone
" " 5.5-5.7 at Padang Sidempoean
" " 5.5 at Si Boeal near Balige--liparite
" " 5.9 at Taroetoeng--liparite
" " 5.7 at Pandeglang--Bantam tuff

Where the rocks are on the acid side, the well waters are thus also apparently so. If on the other hand one looks at the wells in the more basic andesite tracts:

pH of 6.2-6.3--Malang--andesite and basalt
6.5-6.7--Oemboelan Spring (East Java)--andesite and basalt
6.5-6.8--Kota Batoe on Mt. Salak--andesite
6.4 --Tasikmalaja--andesite
6.8 --Takengon--andesite
6.5 --Pengalengan--andesite (Much free CO_2)
7.1 --Poerwakarta--andesite and basalt

then in general these do not fall below pH = 6, and thus are neutral to weakly acid. According to H. A. Middelburg[3] fresh ash from the Merapi, collected at Klaten in Dec. 1930, gave, in water suspension, a pH of 8.5; in spite of the fact that there could not be present any calcium carbonate, it appeared to have a very alkaline reaction. A somewhat older ash soil, but still yet very juvenile, gave a pH of 7.5. However these reactions were determined in water in the absence of carbon dioxide.

Figures for river waters, which may in a certain sense be considered as rock extracts, likewise show a connection with the petrographic nature of the drainage basin:

Djambi river--hinterland: old, acid formation, acid tuff--pH 6.0
Tjiliwoeng-- hinterland: already quite extensively weathered andesite--6.4-7.1
Lematang (Lahat) hinterland: older and younger tuffs, also limestone--pH 7.0
Brantas--hinterland: young ash and marls--pH 7.8-8.2

The water of the artesian wells is more alkaline, the closer the wells are located to the sea, where the water originates from calcium containing layers, especially the marine tuffs; sometimes there is but little lime in the water, but then there is more sodium carbonate (for example, at Batavia!).

Artesian water of the plain of Bandoeng-- pH 7.0
" " " Loeboe Pakam (Sumatra's East Coast)-- " 7.3
" " " Tandjong Priok-- " 7.3-7.6
" " " Djambi-- " 7.6
" " " Lho Seumaweh (Atjeh) " 7.3-8.3
" " " Tandjong Balei (Sumatra's East Coast)-- " 8.3
" " " Padang (Sumatra's West Coast)-- " 7.6-8.55

3. H. A. Middelburg, Diss. Wageningen, (June, 1932).

These examples should be adequate for the present purpose, that is, to show that weathering liquids of very divergent degrees of acidity are active in the Netherlands Indies. Now let us examine how those different liquids act upon the various minerals which were summarized in the diagram (Fig. 1, page 7).

* * * * *

1. Quartz does not dissolve in pure water, it remains unaltered, as also in water containing carbon dioxide. On the contrary--quartz even grows when it comes in contact with water containing silicic acid. In crater water, also, accretion occurs, and, if the precipitation of silicic acid proceeds too fast, a covering with chalcedony or opal takes place which in the course of a very long time can crystallize into quartz.

In an alkaline medium, as in water containing sodium salts of weak acids such as boric acid, silicic acid, and especially carbonic acid, quartz is attacked and very weakly dissolved, though more strongly with higher temperatures. The liberated dihexaeders of quartz resulting from the complete weathering of quartz diorite which, for example, is to be found in Java at Tjiemas, south of Radjamandala, in South Solo, and in the southern mountains to the south of the plain of Malang, are all more or less rough through natural etching by the alkaline liquid originating from the breaking down of the calcium sodium feldspars. If such an alkaline reacting liquid (pH greater than 7) is acidified by carbon dioxide or organic acids, developed or present in decomposing organic materials (bogs, tree trunks) then the silicic acid again precipitates as opal, which later becomes transformed into chalcedony or quartz (petrified wood in Bantam and Djambi, Java).

In short--at less than pH 7 quartz is resistant while it dissolves very slightly at a pH greater than 7.5. The same applies to the other crystallized forms of silicic acid such as chalcedony, and in some andesites, such as tridymite.

* * * * *

2. The feldspars.--These important minerals both in petrography and in soil science form a group which in addition to exhibiting a number of points of similarity, are very different in crystallographic, physical, and chemical characteristics.

Formerly, it was supposed that each sort of feldspar had its definite kind of molecules, which were unalterable and arranged in the crystals in a definite manner in a network or lattice. The nature of these molecules was premised as primary, and the physical and crystallographic characteristics were accepted as the consequence of the nature of the molecules. During these times the feldspars caused serious difficulties.

Potassium feldspar, which is called orthoclase whenever it is met with in old rocks; but sanidine, whenever it is found in younger volcanic rocks, answers to the empirical chemical formula: $KAlSi_3O_8$; while calcium feldspar, anorthite, has the formula: $CaAl_2Si_2O_8$. The difference is so great that one might suppose an entirely different molecular structure, and consequently, besides a different chemical behavior, might presuppose crystallographically, for example, a preclusion of isomorphy. This proved to be the case; orthoclase is monoclinal, while anorthite is triclinal. Now however, albite, (sodium feldspar with the formula $NaAlSi_3O_8$) closely connected chemically with potassium feldspar, according to the old law of Mitscherlich ought to be isomorphic with orthoclase, and also ought to be monoclinic. These statements, however, do not tally with the facts; on the contrary, albite, in spite of the entirely divergent molecular formula, appears to be completely isomorphic with anorthite. While chemically, on the other hand, in so far as both alkali feldspars weather much more slowly and apparently in a different manner than calcium feldspar, albite corresponds more with orthoclase.

Since about 1925, thanks to the X-ray investigation of crystals,[4] radical modifications of the earlier conceptions have occurred. In a certain sense there has been an entire abandonment of "molecules" and of "crystal molecules," which

4. In a lecture (28 Nov. 1931) in the Geological Section of the Mining and Geological Society, of which an author's abstract appeared in: Geol. en Mijnb, No. 19 (1 Jan. 1932), J. M. Bijvoet gave a survey of these important revolutionary ideas, connected with the names of: W. H. von Laue, and W. L. Bragg, V. M. Goldschmidt, followed by a number of other enthusiastic researchers.

were previously thought necessary in order to build up the crystal lattice, wherein the molecules were supposed to be oriented in a definite symmetry. At present, on the basis of the empirical data of the X-ray analysis, crystal lattices are constructed, or, using the more modern phraseology, equilibrium bonds directly connect the atoms (ions). In just the last few years it has been possible to determine with more or less certainty for a number of silicates the method of linkage by which the atoms are built up into crystals.[5] It is unfortunate that the minerals such as the feldspars and kaolin, in which we are particularly interested, are not yet "ready"; therefore at present we cannot go fully into details regarding these investigations. But so much has already been settled that it is admitted that in all silicates each silicon ion is surrounded by four oxygen ions in a tetrahedral arrangement. Further, that the four following groups of silicates can be differentiated:

a) Linakges, wherein each O-ion belongs to only one Si; all SiO_4 groups are thus independent; they are electronegative and are mutually connected by electro-positive metallic ions, spaced in all directions. Such crystals have therefore, no direction of fracture easily determined in advance (garnet, for example).

b) Linkages, wherein in one direction SiO_4 groups are held together by a common O-ion. They thus form chains or strings of indeterminate length. The crystals then form threads, filaments, or needles, of chain-like structure and with the consequent tendency to split, such as pyroxenes, amphiboles, and asbestos.

c) Linkages, wherein the SiO_4 groups are repeatedly connected with three others and thus form a network in planes, membranes or leaves of indeterminate dimensions; these are then mutually united by metallic ions which lie in between.

d) Linkages, wherein the SiO_4 groups have all their O-ions united with other Si ions. There is then no tendency to split along any special line or plane; this is why quartz, for example, has no planes of fracture.

* * * * *

Now in weathering, these linkages have the following significance: if it is taken for granted that the Si-O-Si linkages are so strong that they are attacked only by drastically strong reagents, while weathering processes are not able to attack them or only with difficulty:

With a) the weathering can penetrate in on all sides between the groups with a Si nucleus; but whether or not this succeeds depends upon the manner of linkage. Anyhow there is no preference as to direction.

With b), the weathering (hydrolysis) will probably be able to penetrate in the direction of and along the chains. Then if the metallic ions lying in between are replaced by H, the crystals are then often disintegrated into fibers (for example, serpentine).

With c), the leaves remain, but are more or less loosened from each other; the weathering penetrates, as it were, as water into a bundle of sheets of tin, so that upon disintegration there are obtained scales rather than filaments, and finally

With d), the permanent net connection remains. Quartz has no metallic ions replaceable by H, and only by very drastic reagents can the lattice be attacked.

Now let us return to the feldspars: Although the structure has not yet been fully explained nor definitely established, so much has already been found that one might say that the feldspars most probably belong to type c mentioned above. Here the relationship with scaly micas and kaolinite is evident. But it has further been found that to a certain degree Al can replace Si in the "frame" and is then also surrounded tetrahedrally by four O-ions. Yet unlike Si, its electric charge is then not four, but only three. Now whenever in Na-feldspar one equilibrium linkage is

5. Compare, for example, W. L. Bragg, The structure of silicates, Z. schr. f. Krist, 74, (1930), p. 237-305, where are important references to the literature.

built up, then this can be maintained, as soon as one Si'''' is replaced by one Al''', provided then at the same time one Na', is replaced by a bivalent ion as Ca'', so that electrical equilibrium remains. Further, this replacement is therefore possible in the lattice, because the volumes of the Na' and Ca'' ions do not differ so much; the ray of the Na' ion is viz. 0.98°A, that of the Ca'' 1.06°A. On the other hand the ray of K is 1.33°A; the K' ion is thus evidently "too thick" to be able to take the place of the Na'; the potassium feldspar must therefore look for a different equilibrium bond, one with its own characteristics.

This explanation, which even today is still hypothetical, does seem to explain the crystallographic characteristics of the three feldspars, but there is still something more to be said. What must still be explained is why Na feldspar is chemically so much more closely related to K feldspar than to Ca feldspar.

With pure hydrolytic weathering both alkali feldspars give kaolin, while it is doubtful if calcium feldspar does; in fact there are indications that calcium feldspar does not give kaolin at all. (We shall return to this on page 80). Now if we accept the theory that in the linkages of 3 Si, there is only one Al, the linkage remains, while whenever, as in calcium feldspar, 2 Si have 2 Al, the bonds are not resistant against hydrolysis and break down. Then it seems that the difficulty is overcome with the just mentioned newer crystal conceptions. But if one then realizes that kaolin with the empirical formula: $H_4Al_2Si_2O_9$ originates from alkali feldspar ($M.AlSi_3O_8$); the kaolin has exactly that combination Al_2Si_2, and since kaolin is the most resistant against hydrolysis, then we are again faced with contradictions.

In the last few years interesting investigations have been carried out by various American researchers,[6] from which it appears that in many cases the composition of "kaolin" is not so simple as was previously supposed. Though it was known that now and then kaolinite crystallized out from clay, earlier it was held that "clay" was amorphous. In two different ways, first from studies of double refraction[7] of the very fine clay particles and second from investigation with the aid of X-rays, it now appears that the clay is, for the greater part, crystalline. The defraction figure of the crystal lattice is dependent only upon the part of the clay which behaves as an acid, called the "acidoid" and independent of the absorbed cations. On these grounds the small minerals may be divided into three groups:

1. the kaolinite group, to which there belong, besides kaolinite:

   halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$)
   anauxite ($Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$)
   beidellite[8] ($Al_2O_3 \cdot$ 3 or more SiO_2, about $4H_2O$)

   The last frequently contains Fe_2O_3, partially replacing Al_2O_3, thus as an isomorphic admixture of nontronite ($Fe_2O_3 \cdot$ 3 or more $SiO_2 \cdot$ about $4H_2O$)

2. Montmorillonite (Ca, Mg) O, Al_2O_3, about $4SiO_2$, about $5H_2O$

For 1--the refractive index is about $\alpha = 1.561$; - $\gamma = 1.567$ and for 2--the refractive index is about $\alpha = 1.495$, - $\gamma = 1.520$ (free from iron!)

Whenever iron oxide is taken in, as in the minerals beidellite and nontronite, then the refractive index is much higher.

According to the investigations mentioned, it appears that not kaolinite, but beidellite and montmorillonite are the most frequently occurring "clay minerals. Without desiring to contradict this, we would like to point out that in the

6. C. S. Ross, The mineralogy of clays, Proc. First. Intern. Congr., Soil Sci., 4 (Washington, D. C., 1927), p. 555. Cf: E. John Russel, Soil conditions and plant growth (1932), p. 171. E. T. Wherry, C. S. Ross and P. F. Kerr, Coll. Symp. Ann., 7 (1930), p. 191. S. B. Hendricks and W. H. Fry, Soil Science, 29 (1930), p. 457.
7. C. E. Marshall, The orientation of anisotropic particles in an electric field, Trans. Farad. Soc., 26, pp. 173-186.
8. This name comes from Larsen and Wherry, Journ. Wash. Acad. Sci., 15 (1925), p. 465.

researches referred to more material of the temperate zones of the earth than of the tropics was investigated; here in the tropics it might be quite different, though the findings may apply equally well. Speculations as to these points are valueless; one simply must investigate.[9]

But however this may be, one thing is here worthy of recording and it is this: through direct observation small crystalline minerals, in part cryptocrystalline, have been demonstrated in the fine fractions of all kinds of soils. Even recently many researchers supposed such fractions to consist only of amorphous colloids in the form of a colloidal mixture of silicic acid, iron oxide, and aluminum oxyhydrate, all three in gel form.[10] To suppose that there exist in those small crystalline minerals nuclei which are resistant to the weathering agents thus seems to somewhat lose its speculative character and it appears by no means improbable that, when more is known of the crystal lattice of the small minerals, as well as of that of the minerals present in the igneous rocks, the different behavior during weathering of alkali feldspars and calcium feldspars will then be better elucidated.

An important point will then be whether by means of that structure it will also be possible to explain how in the formation of kaoline from alkali feldspar, 2/3 of the silicic acid can be washed out, while 1/3 remains behind in the kaolin. If this observation, which perhaps is still somewhat inadequately substantiated, will with further research be established as a firm, generally accepted fact, then without doubt we will know whether to admit that the feldspar Si is in two forms or whether upon weathering a complete destruction of the feldspar bond is instantly followed by the building up of the new kaolin linkages. The latter must then be entirely different from those of the calcium feldspar, because although both possess the group Al_2Si_2, kaolin is very resistant against weathering, while anorthite is just the opposite.

* * * * *

Proceeding from the hypothesis which, as already stated, ought to be proved experimentally somewhat more conclusively, namely, that hydrolysis of alkali feldspar gives kaolin and free silicic acid, while on the other hand calcium feldspar gives free aluminum hydroxide (hydrated gel or sol) and free silicic acid (also hydrated gel or sol), there now follows consideration of the course of the weathering of the feldspars as affected by the action of the above-named (pages 72-74) 7 weathering liquids.

We may begin with the action of pure water. Water hydrolyzes directly; K or Na atoms are liberated, H atoms are taken in. It is now no longer a question whether for this to occur, it is necessary that first a whole "molecule" of feldspar must go into solution in order to split up. Formerly that was believed to be the necessary condition to bring about chemical reactions. At present we know that it is not necessary for this to take place, because chemical reactions can occur on the surface of solid substances in contact with a liquid; and exchange of certain ions, for example, such as H' with K' or Na' can occur until a definite concentration of metallic ions is built up in the liquid.

Whether the 2/3 of the silicic acid, which was mentioned above goes into solution also as ions, for example as SiO_3, rather than as undissociated molecules, has not yet been clearly made out; only this is certain: that silicic acid enters the liquid, though perhaps not so readily as K or Na ions. Further there occurs a reaction between the dissolved K

9. Ross makes the following statement, which is still very generally held: "It is evident, that there is a relation between the type of clay mineral and the climatic or other physical conditions under which it is formed....Preliminary studies indicate that more aluminous clays are likely to develop where weathering is deep and profound as in the southern states, and the more siliceous ones where weathering is less profound." (L. c., p. 561.)

10. Cf. for example, Harrassowitz in "Boden der tropischen Regionen," Handbuch der Bodenlehre III (1930), p. 362. He there speaks of: "A complete cleavage of the molecule (during weathering) when silicic acid and alumina are completely separated,...."

and Na ions and the dissolved, although perhaps, at first, not dissociated silicic acid, in this manner:

$$2K^+ OH^- + SiO_2 = K^+ + K^+ + SiO_3^{--} + H_2O$$

thus it is to be expected that next to the K ions SiO_2 will appear; so that K or Na-silicate in true solution, as ions, is found in the liquid. As carbonic acid appears in the field, however, the silicic acid is again pushed back into the undissociated form. (More about this later.) These various points can be clearly demonstrated by dialysis.

What happens to the residue of the feldspar robbed of the K or Na, as well as of the SiO_2? Perhaps it is not necessary for this to go first into solution in the liquid, in order afterwards to precipitate out from it as undissolved, solid kaolin; presumably it simply remains behind as insoluble kaolin. This kaolin would exist as a cryptocrystalline colloid, with true colloidal properties such as the power of adsorption of ions, both metallic and hydrogen ions.[11] If we accept the above to be the case, then directly upon or after the formation of the residue, it at once acts as would an insoluble kaolin, absorbing K or Na ions and releasing H ions.

There is thus left over from the feldspar: undissolved kaolin, to a certain degree absorptively saturated with K or Na ions, and in the solution free alkali or dissociated alkali, silicate and perhaps also free undissociated silicic acid. Besides that, undissolved silicic acid in gel form may remain over at first or when there is little liquid.

If now the water is continually replaced by fresh portions[12] then the dissolved constituents go away with it; any undissolved silicic acid, if there be any, and the kaolin remain behind. As the kaolin layer around the undecomposed feldspar becomes thicker and more inhibiting, the dissociation of the feldspar, while it can continue uninterruptedly, will be slower and slower in proportion to the thickness of the kaolin layer; consequently, in a continually scoured river bed there can take place perhaps in days or weeks, a process which in a quiet undisturbed place might require years or even centuries.

Finally the feldspar is dissolved. If the water continues to circulate then the concentration of alkalies will continue to decrease and the absorbed alkali ions will be slowly but certainly leached out from the kaolin and replaced by H. Now with this is connected a new phenomenon: the pure kaolin, only containing hydrogen, changes from the gel state into the sol state, and becomes movable. It goes on with the water to some other place and finally none of the original alkali feldspar is left.

There are thus carried away to some other place: alkali and silicic acid in the ionic form, then silicic acid in undissociated form and perhaps also as a sol, and finally kaolin in the sol state. If the latter is carried into some place where the sol again becomes unstable, then the sol precipitates again as a gel, as for example in a kaolin layer.

Now, whenever the pure water contains more or less carbonic acid, what happens? --As long as the pure water carries away alkali in solution, whether or not the alkali is combined with SiO_2, the reaction is alkaline, i.e. the pH is higher than 7. If CO_2 enters into the solution, then the pH is lowered, to 7 (neutral) and to as low as 5 (moderately acid). The importance of this is that the alkalies are more soluble in carbonic acid solution than in pure water; that the kaolin will be less saturated with absorbed alkali ions, and that the silicic acid on the one hand, if in an alkaline medium is carried away in the ion form, and on the other hand, if in a more acid medium there is less of a tendency for its transformation from gel to sol form, and more remains behind. And

11. To here take up at length the whole "double ion mantle theory" would take us far too far afield; for this we refer the reader to the Handbuch der Bodenlehre, 8, 322, and a number of other publications; as those of Kappen, Wiegner, etc.

12. When, such as in deeper layers of rock, that replacing by fresh water takes place very slowly, or almost not at all, through the interaction of the constituents in solution there can crystallize as intermediate stages all sorts of "zeolites," some with a lattice or bonding from which kaolin minerals can later originate, others with which this does not take place.

finally, although it is more rapidly lost in that medium, the kaolin also will be less inclined to go over from the gel into the sol form, in an acid medium. In composition the final product will be an undetermined mixture of the two gels, namely kaolin and silicic acid. Then after a very long time the fully leached-out kaolin crystallizes to larger scales or plates of kaolinite; the silicic acid becomes chalcedoney and quartz.

As to whether in pure water or in water containing carbonic acid the kaolin will be split up into alumina and silicic acid, has never been proved nor even shown to be probable. In those cases wherein one apparently observes a dispersion of silicic acid and alumina, another explanation (see further on!) is much more likely.

Whenever humous water acts upon the alkali feldspars, that water as a rule also contains carbonic acid, but the acid humus materials lower the pH still more than does the CO_2. Saturated only with CO_2, water cannot go below pH 3.85, but humous bog waters in the Netherlands Indies exhibit pH figures which fall to 3.7, while in suspensions of peat bog soil, figures as low as 3 to 2.8 have been established.[13] The consequence of this is that the alkalies are more rapidly washed out than with CO_2 alone, the kaolin will be poorer in alkalies and richer in H, and there is afforded still less opportunity for a change from the gel state over into the sol. Mom[14] determined that the clay colloids occurring in natural (river) waters remained in the sol form even during repeated acidifying to as low as pH 4, but in every case acidifying to 3 coagulated the colloids to solid gel floccules. Also in this case there is no further question that the reversal of the effect will occur. In addition, less of the silicic acid, as with kaolin, is carried over into the sol form and hence less is carried away. Also because of the stronger carbonic and humus acids, it has no chance of going into solution as ions. The result is the same as that produced by water containing carbonic acid, but more permanently and more easily.

The crater water which sometimes contains as much as several per cent of free hydrochloric and/or sulfuric acid, which gives an acidity or pH of about 1 down to 0.5, is really no longer an ordinary weathering water; it is a strongly acid liquid of exceptional nature. Consequently it attacks the feldspars differently: This acid water extracts all alkalies quite rapidly and through solution of the aluminum as sulfate leaches the kaolin nucleus, while the silicic acid which is separated out of the kaolin is that silicic acid that above is differentiated as the 2/3ds of the total silicic acid which is dissolved out. In this intensely strong acid liquid the silicic acid is, however, no longer entirely insoluble; at least not at the instant that it is formed; therefore the crater water which flows off carries with it appreciable quantities of SiO_2, although it is yet uncertain as to which form it exists in. Certainly not as the usual SiO_2 ions; perhaps it is as a - or + "charged" SiO_2 sol. If SiO_2 is once precipitated from the solution and becomes solid and dehydrated, then it is practically insoluble in the acid; it is because of this that in craters and around solfataras one finds so much silicic acid as silica sinter. (Such silica is often mixed with sulfur.)

While we have been speaking of what happens to the alkali feldspars in neutral to acid weathering liquids, we will now discuss the calcium feldspars, the anorthite as well the plagioclase series. We have already proposed the hypotheses (page 77) that calcium feldspar upon hydrolysis should not give kaolin, but rather, besides calcium ions, dehydrated aluminum hydroxide; the latter two products might occur either in sol or gel form, or in true solution. Now since calcium feldspar, in so far as it occurs in plagioclase or even in orthoclase, behaves in the same way, we arrive at the following cases:

In pure water calcium leaches out, and raises the pH above 7. If both silicic acid and alumina are dissolved in the alkaline liquid, then at relatively high concentrations they precipitate out,

13. Cf. A. Kortleve, Arch. Rub. Cult., 12 (1928), p. 610; W. A. J. Oosting, Landbouw IV, p. 240.
14. C. P. Mom, Coagulatieproc. b/d zuivering v. drinkw., Meded. Burg. Geneesk. D. in Netherlands Indië, 1 (1925), p. 41-43.

forming the difficultly soluble and often H-containing calcium silicates (zeolites). The reaction then again becomes almost neutral and the aluminum hydroxide remains behind, while a part of the SiO_2 disappears. But in case of the dissociation of plagioclases, Na and perhaps also K ions in the solution are present as well as insoluble kaolin. The latter can absorb Ca ions, which come into action from the free silicic acid, and, if the reaction is fully alkaline, from the alumina also. However, the silicic acid is more effective in this respect than the alumina.

If the penetrating water contains dissolved carbonic acid, which at low concentrations depresses the pH to 7 or 6, and at stronger concentrations from 6 to 5, then calcium is considerably leached out, while alumina and silicic acid are to a smaller degree. It is apparent that when pH figures are between about 7 and 5.5 silicic acid is leached out, but aluminum hydroxide is not, probably because none is present. For Mom[15] has stated the "practical limits of the possible existence of aluminum hydroxide are between pH 5 and 7." The degrees of acidity concerned are such that even alumina coagulates out of the sol form; hence the solution of precipitated alumina need not be expected. The result will thus be that: the calcium, except that part of it which is absorbed by the kaolin resulting from the weathering of the plagioclase, goes again into solution as the bicarbonate; the alumina remains behind as a gel; the silicic acid, perhaps originally present for a long time as a gel, yet goes away as a sol. If SiO_2 is gone then there are left only kaolin (meanwhile de-based) and alumina. If now the CO_2 content in the water becomes less, then the pH rises to between 6 and 7 and the kaolin can disperse and leave as a sol; the final result is nothing else but hydrated Al_2O_3, perhaps in part crystallized as hydrargillite (= gibbsite) or as diaspore.

If we now follow the action of humous water with a pH of 5 to 3, with reference to the calcium nothing new arises. With the Al_2O_3, however, something different does happen: if the pH falls below 5, then the Al_2O_3 goes into solution, originally as a sol, but ere-long as Al ions. The strength of this solution is proportional to the acidity of the liquid. Besides this acidity of the humous water, it is important to note that electronegative humous particles (micella) occur in it. Now where the alumina micella are electro-positive, they will attract the humus micella; the latter will then envelope, or perhaps better said, surround the particles, and through their strong charge "transfer the charge" and, acting as a "protective colloid," hinder their flocculation; in other words, if an alumina micelle gets into the liquid, it is made permanent as a sol and protected against flocculation or precipitation. Since the Al_2O_3 as a sol is attracted by the humus-sol, the Al_2O_3 gel goes over gradually into the sol condition and from its original place disappears with the liquid. Silicic acid is, however, negatively charged when it comes into the liquid as a sol, hence it is repulsed by the humus sol micella. The result is that there is no protective action. SiO_2 cannot dissociate to an important degree in the presence of very acid humus acids, hence for the greater part silicic acid remains behind, or at least it dissolves very much less rapidly than at pH figures of about 6 to 7. The result is that in this case the silicic acid, not the alumina, remains over. The kaolin, too, remains behind because those particles are also negatively charged. Yet it appears that the "charge" of the kaolin can to a certain degree be also "transferred" and protected by the humus acids. However, this cannot be of great importance because, as we shall see, it is in bog tracts under the peat where as a rule more or less silicic acid-containing kaolin is found.

In crater water with its strong acids, the calcium feldspar undergoes, probably more rapidly, the same decomposition as the alkali feldspar. Calcium and alumina go into solution as Ca and Al ions, and silicic acid for the greater part remains behind continually becoming more resistant, in proportion to its degree of dehydration.

Let us now turn to the weathering liquids with a pH greater than 7, that is

15. L. c., p. 54.

the waters which have an alkaline reaction.

If while flowing through limestone, water, containing carbon dioxide, becomes saturated with calcium and therefore has its pH raised, then that pH can increase to 8.4 as a maximum. However if water without the aid of free CO_2 is saturated with $CaCO_3$, then, even at low concentrations the pH can rise to 10.2. In nature, however, it is extremely seldom that such water actually occurs.[16] Such water, acting upon feldspars, is unable to leach out from the calcium feldspar any or at most not very much Ca. From the alkali feldspar however K or Na is removed in the ionic form and Ca is left in place of them. If, however, the concentration is lower, then the alkali feldspar, when once attacked, decomposes more rapidly. Thus with a pH higher than 7, in addition to Ca, one obtains also K and Na as ions in the liquid, and also kaolin from the alkali feldspar, which is saturated with K and Ca ions. Also one obtains silicic acid, which ionizes, and finally alumina, which acts as an acid, as well as acid ions (AlO_3^{---} or $AlO.O^-$). The more CO_2 present in the water, the more the alkaline reaction is reduced; the pH falls to about 7 and sometimes even lower. The principal change in the weathering picture with the lowered pH is that less and less Al_2O_3 and finally none at all goes into solution, while silicic acid is dissolved and carried away.

If with respect to the Ca ions, such alkaline water possesses relatively much K and/or Na ions then whenever such water circulates through alkali feldspars and there takes up new K and Na ions, calcium is still separated out as calcium carbonate; but from alkaline liquids kaolin can also absorb Ca and therefore liberate K or Na.[17] From the experiments of Bradfield and Cowan one might conclude that from an alkaline, Ca-containing soil liquid, more Ca would be absorbed as the pH becomes higher, while the leaching out of K and Na would not be much affected by the pH. On the contrary, alumina is leached out with a pH less than 4.5 and greater than 8, while the silicic acid, at pH 7.5 to 10, practically remains insoluble, yet dissolves at pH 7 or lower. The latter phenomenon appears strange, and not in agreement with other experiences. Only the greater tendency of Al_2O_3 than of SiO_2 to disappear with strongly alkaline and strongly acid liquids, and the stronger disappearance of SiO_2 along with the immobility of Al_2O_3 when the pH values are between 4.5 and 7.5 is in full agreement with what was stated above.

From some artesian wells in the Netherlands Indies flows alkaline water which is colored strongly brownish by the organic materials present in it. The analysis shows pH figures between 7.5 and 8.5, and in addition to considerable sodium carbonate and bicarbonate, a notable amount of SiO_2 but no Al_2O_3. This SiO_2 may be present as an ionized Na-salt, but may be also in sol form, the organic material serving as a protective colloid. The analyses recorded by Mom,[18] however, make it clear that the latter is of no importance, since the quantity of SiO_2 in ionic form sometimes greatly exceeds the total quantity of organic matter. The Na solution thus takes the SiO_2 with it in ionic form and from the plagioclase there remains behind in the soil a Na saturated kaolin in addition to hydrated aluminum hydroxide.

Let us consider finally the action of sea water on the feldspars. Sea water is differentiated from river water and other weathering liquids by its high content of NaCl, besides which there are present KCl, $CaCl_2$ and $MgCl_2$, as well as sulfate ions, though all the latter are present to a lesser degree. The pH is from 7.8 to 8.4, thus sea water has an alkaline reaction. Now a peculiarity is this, that while on the land the plagioclase as a rule weathers more rapidly than orthoclase. In sea water the reverse seems to be the case, especially in connection with the Na-rich and Ca-poor sorts of plagioclase. Thus those that closely approach albite, can remain bright and fresh in sea water,

16. Cf. H. Kappen, Handbuch der Bodenlehre VIII, 324.
17. Cf. Handbuch der Bodenlehre VIII, 243, where there is a reference to: R. Bradfield and E. W. Cowan, The effect of the hydrogen-ion concentration upon the absorption of calcium by a colloidal clay, Soil Sci., 24 (1917), p. 365.
18. C. Mom, Jaarversl. Proefst. Manggarai over 1930, p. 27.

while the K feldspar becomes definitely clouded and weathers. That is not to be wondered at when one considers the high concentration of Na ions in sea water as compared with the amounts of the K and Ca ions; therefore the possibility of exchange for Na is small in the feldspar, but the K and Ca of the feldspars are much more easily exchanged for Na from the rich supply. So the exchange does not appear to take place, for in and near to the calcium-rich feldspars there often forms calcium carbonate. And what is more important is that whenever such feldspars, which have been exposed for a long time to the action of sea water, come "above water" and are exposed to fresh water, then the K- and Ca-rich feldspars are quickly weathered "away," while albite and Na-rich oligoclase still appear completely fresh. If, on the contrary, a granite containing orthoclase besides considerable calcium-rich plagioclase, weathers in a humid, tropical climate, then the latter is rapidly weathered, since through the disappearance of the calcium in the plagioclase structure, a breach is made and further hydrolysis can take place with less hindrance. Apart from this action of the cations Na^+, K^+, and Ca^{++},--(and also Mg^{++}, as we shall later see),--the sea water, through its content of salt, is also significant in another way. In the first place since the strong salt solution flocculates out all colloids as gels, or holds them insoluble as gels, neither kaolin, nor SiO_2 nor Al_2O_3 can assume the sol form. Secondly, in the alkaline medium, the gels cannot react as acids, or, in other words, since there is no opportunity for a strong saturation with H ions, the kaolin, for example, for the greater part will be saturated with absorbed K, Na, and Ca ions. Colloidal silicic acid cannot exist as such; besides it goes over into other combinations with which we will deal later.

These facts ought to be sufficient to demonstrate that under the different conditions of weathering mentioned, the course of weathering for the feldspars is very diverse indeed!

Let us now look at the other minerals.

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3. The micas. Of these we shall first speak of:

a. Potassium mica, even though in the Netherlands Indies this mineral occurs in relatively small amounts in the soil-forming rocks. In a certain sense potassium mica occupies an intermediate position between potassium feldspar and kaolin.

Where the weathering of alkali feldspar proceeds slowly, as a rule there may be observed scales of muscovite, that is, potash mica, on and in the orthoclase. And in the kaolin originated from muscovite granite, sometimes the sole impurity--besides of course the unweathered quartz--is only a little muscovite, less than the original rock possessed. This makes quite likely the composition as stated. According to the chemical composition, the muscovite, in comparison with the potassium feldspar, has lost the already-mentioned 2/3rds of the silicic acid; so that the relationship 3 Si to 1 Al has already become 1 Si to 1 Al, as is also the case with kaolin. At the same time approximately 2/3 of the K has been replaced by hydrogen. Muscovite weathers slowly; its resistance is the same as that of kaolin; perhaps the lattice or the linkages show sufficient points of agreement. The investigations of Mauguin[19] have shown important data on the subject of the leaf or film structure of the micas, and those of Gruner[20] with respect to the structure of kaolinite; but as yet we cannot speak with assurance of the relationships.

Be that as it may, the fact is that in either case the muscovite also goes over into kaolin, or in other words, upon weathering in water with a pH of between 7 and 5 it gives kaolin, which later cannot be distinguished from the kaolin derived from orthoclase. The constituents liberated upon the hydrolysis of potash mica: the K ions in solution and kaolin with absorbed K ions, if any, behave in the liquids of different degrees of acidity circulating around them, apparently in just the same way as if they had originated from potash feldspar; hence here nothing further needs to be said about them.

19. C. Mauguin, C. R., 186 (1928), p. 879 and 1131.
20. J. W. Gruner, Z. f. Krist., 83 (1932), p. 75.

b. The iron magnesia-micas, the so-called dark micas, are found much more abundantly in Netherlands Indies rocks. Their chemical composition is very complicated and variable; numerous formulas have been proposed for them, but it is still very much a question whether it will be possible to express that composition in a formula of the sort used until recently. We shall therefore not concern ourselves with this, and only state that the micas in question, together with silicic acid and alumina, contain magnesia and iron oxide (in ferrous and ferric forms), and besides, at times, important quantities of other ions, such as K, Na, Mn, Ca, Ti and sometimes Li, and F. Moreover, they all contain water (or hydrogen). They weather much more easily than muscovite; by hydrolysis the magnesia and the iron are quite easily liberated from the crystal bonds of the mica plates. Now how do magnesia and iron behave (the latter again to be differentiated into the ferrous and ferric forms) in the presence of the different weathering liquids?

In some respects magnesium acts similarly to calcium; with much pure water Mg is washed out in the ionic form, but more slowly than the Ca. This is true, not because Mg is less soluble than Ca, but because Mg so readily forms combinations with silicic acid and water, such as talc and serpentine which are practically insoluble in pure water. Presently we will come back to this point.

As the pH becomes lower, that is, as the liquid becomes more acid, for example from carbonic acid, the Mg goes into solution as $Mg^{''}$ ions and is carried away; thus CO_2 furthers the washing out of Mg. Now if humus acids come into the picture, then this leaching proceeds still faster, while in crater water, washing out proceeds even faster. In alkaline water the reverse is true. Then not only the above-mentioned hydrated Mg-silicates will be resistant to solution, but also $MgCO_3$. As the pH rises above 7 the Mg becomes more stationary, more resistant.

And now as to iron: As the bivalent Fe^{++}, iron is very sensitive to oxidation and whenever oxidation is at all possible, it goes over into the ferric form. Iron from silicates is not appreciably leached out in pure water without O_2 or CO_2. If, however, the water contains CO_2, then the pH falls below 7 and the Fe^{++} goes into solution as ferrous carbonate and is leached-away with Mg, Ca, K, and Na carbonates. --If the water contains only O_2, then the action proceeds very slowly; but if there is CO_2 in addition to O_2 present in the water, then the CO_2 assists the hydrolysis, which is directly followed by oxidation to the ferric form. But it does not continue to exist as carbonate; the CO_2 is again freed and ferric hydroxide remains over; the CO_2 can again leach out ferrous ions, etc. And so with little CO_2 and much O_2, ferrous iron can be transformed into ferric hydroxide.

In the kinds of micas containing iron, the iron occurs in both the ferrous and the ferric forms; and this explains the mixed green and brown colors. In the case we are considering, in water with O_2 plus a little CO_2, the mica becomes browner and browner, and so long as it preserves its crystal bonds, it remains clear. If, however, CO_2 predominates, more ferrous iron leaches out, (which disappears) then ferric iron precipitates, and the color becomes brighter brownish yellow; indeed, the greenish accessory color disappears.

But now whenever humus materials are present in the water, so that certainly CO_2 is present, but no longer any O_2, then not only is ferrous iron leached out, but also ferric iron; even precipitated ferric hydroxide is no longer able to resist, for ferric hydroxide behaves in just the same way as does the aluminum hydroxide already described above. As the pH is lower, the ferric hydroxide allows itself to be taken in tow by the humus colloids, acting as protective colloids, and it is taken away in the sol form just as the colloidal alumina was. For the mica, the first certain result is that it becomes completely bleached, while its crystal bonds still remain intact. If there were no other optical characteristics to make possible the differentiation, one might mistake such colorless mica for potassium mica or muscovite. Especially the low, peaty coastal stretches of Sumatra provide, here and there, striking material for observation of the phenomena as here described. Supplementing these observations in the form of corresponding chemical analyses would without doubt be interesting

and of value.

The bleached mica which has been leached out, robbed of Mg and Fe, is yet strongly attacked, and as a result of hydration, (not through hydrolysis), falls further apart into small kaolin-like scales. Will they really be kaolin as was shown above in the case of muscovite? There may also be a question regarding one of the other minerals, named on page 77. Precise, combined X-ray and chemical research will have to be used to make sure about these points.

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4. Amphiboles (hornblende) and pyroxenes (augite and hypersthenes)

Formerly this group of minerals was always called and continues to be called the metasilicates, a term derived from metasilicic acid H_2SiO_3. Just as for the micas, it is impossible to give a satisfactory chemical formula for these minerals:[21] however, for the purpose here designated it is not necessary. If we but know what the different constituents do upon weathering, it is enough. From Table 7 on page 14 we see that many constituents can be present in the amphiboles and pyroxenes; and not all the elements are listed. Considering the broader aspects, we observe that, besides SiO_2, in the amphiboles, MgO, CaO, and FeO are the most important, but in addition to these there also regularly occur Fe_2O_3, much Al_2O_3 and Na_2O. We note that in the augites the dominant element is CaO, followed by MgO and FeO, then somewhat less Al_2O_3 than in the amphiboles, and also Fe_2O_3 and at times quite a good deal of TiO_2; while in hypersthenes CaO is present in small amounts, and besides SiO_2 we really need to consider MgO and FeO, (although there are special cases where hypersthenes are found with more than 10% Al_2O_3 and 4% Fe_2O_3).

X-ray research has shed much light on the differentiation of the minerals according to their crystallographic-optical characteristics. As has previously been briefly touched upon (page 76), in these minerals we have to imagine chains or filaments of SiO_2 groups. These chains are arranged parallel to each other, and are mutually connected by metallic ions. So it is, at least, in the case of the pyroxenes. With the amphiboles, it is somewhat more intricate, since two of those chains form a so-called double chain, viz. by means of the Si-O-Si linkage; Si_4O_{11} groups are found in place of SiO_3 groups. Apart from this, the filaments or double chains are tied mutually together by metallic ions. It is obvious that the hydrolysis makes its first appearance in the crystals parallel to the fibers; through this the fibers or filaments are loosened from each other, and there follows rupture, complete disintegration, a loosening of all crystal bonds, and the metals are replaced by H.

Do pyroxenes and amphiboles upon weathering behave extremely differently? --Not differently qualitatively, though quantitatively so, in so far as the iron-rich and calcium-rich members of the groups hydrolize most rapidly and are thus decomposed. The lime and iron then behave precisely as has been described above under feldspar and iron mica. If carbonic acid is available, the calcium in an alkaline medium can temporarily crystallize as $CaCO_3$, whereas in the long run and especially in acid surroundings, it dissolves and disappears. In conditions favorable for it (much water, CO_2 and no O_2) the iron can more or less disappear, but as a rule, in the presence of water, plus little CO_2, plus oxygen, it will precipitate as ferric oxyhydrate. In humous water with a pH of 3 to 5 the iron goes away, either as ferrous bicarbonate, or as a sol of ferric hydroxide, protected against precipitation by the humus sols. Nevertheless, if such sols are strongly aerated as, for example, the brown water of a brook coming from forest peat, high in the mountains, rustling downward and on farther over a stony bed in an open terrain, then the acid humus sols oxidize away, and the iron hydroxide precipitates, frequently as blackish brown crusts on stones lying in the stream.

In the long run the originally

21. The difficulty lies in that we do not know which constituents participate in the actual crystal net itself (the structural linkages), and which constituents are held in looser union.

brownish-yellow precipitated iron oxyhydrate has the tendency to go over into forms containing less water. From brown iron ore there thus form a series of minerals poorer in water, for which we find the following formulas given:[22]

Limnite	$Fe_2O_3 \cdot 3\ H_2O$
Xanthosiderite	$Fe_2O_3 \cdot 2\ H_2O$
Limonite	$2\ Fe_2O_3 \cdot 3\ H_2O$
Goethite	$Fe_2O_3 \cdot\ H_2O$
Turgite	$2\ Fe_2O_3 \cdot\ H_2O$
Hematite	Fe_2O_3 -

In water alone not a single number of this series changes from a lower towards a higher form; but in acid water with organic material each member may become peptized to Fe_2O_3 sol, and then again precipitate. In the Netherlands Indies we shall come across examples of this.

It is further remarkable that kaolin never originates from amphiboles and pyroxenes with Al_2O_3; the Al_2O_3 exists combined in other ways than it is in the alkali feldspars and micas. The result of the weathering in water with a pH of 7 to 6 or 5.5 is therefore that all the SiO_2 goes away in sol form, following the Ca, Na, K, and Mg, so that only Fe_2O_3 and Al_2O_3 remain behind in the hydrated form. If titanic acid be one of the constituents, then titanic acid also remains behind. If the weathering liquid is strongly alkaline, and the pH greater than 8.5 (for example with the leaching out of plagioclase with little CO_2) then, it is true, Al_2O_3 goes along with it; however such a situation seldom occurs in nature.

If, besides CO_2, humus colloids occur in the liquid with a pH of 5 to 3, then silicic acid and the sesquioxides reverse their role: silicic acid remains behind as a gel (for example opal), while Fe_2O_3 and Al_2O_3 go most actively into solution as sols. A little of the SiO_2 of the amphiboles and pyroxenes remains over. In crater water, this is also the case. In West Java I have collected in craters andesite fragments in which the angles of the feldspar and augite crystals were still sharp enough to measure, and yet those crystals were not there, only SiO_2 and H_2O were left, plus a little pyrite.

* * * * *

5. Olivine

In its occurrence in the Netherlands Indies this mineral is pretty well limited to basalt, which occurs on practically all the islands, and to the peridotite which is found only on Borneo, Celebes and a few other islands in the neighborhood. Olivine is a silicate of simple composition; the Mg salt of orthosilicic acid, Mg_2SiO_4, wherein one part of the Mg is replaced by Fe^{++}. The X-ray analyses of the crystals show that separate tetrahedral groups occur with 4 O's and 1 Si in the middle, mutually connected together by the bivalent Mg^{++} and Fe^{++} ions, which can be attacked by hydrolysis. This mineral, especially if it be rich in iron, is the most easily decomposed of all silicates in weak weathering liquids. And then the Mg and the SiO_2 go away, while the Fe remains behind as ferric hydroxide. In liquids containing humic acid, however, the Fe goes away and SiO_2 remains over; just as with the pyroxenes.

Now, however, something more about magnesium. The MgO content increases from magnesian mica ⟶ augite ⟶ hornblende ⟶ hypersthene ⟶ olivine, and therewith the chance increases that serpentine will appear among the weathering minerals. This is also a magnesium silicate, but containing water; owing to a small iron content the color is most times olive green to dark green. As already stated, serpentine is almost insoluble in water; and likewise in alkaline liquids. In acid weathering waters, the stronger the acid the more the serpentine is attacked, losing its bases MgO and FeO.

In connection with this it will be understood that in sea water practically all Mg-rich minerals will form more or less serpentine, that is, will become serpentinized. This explains the greenish tint of most marine tuffs. In the first place the sea water is alkaline. In the second place, in those tuffs under the sea there cannot be much question of penetration of oxygen, hence no possiblity of the oxidation of iron, but rather a reduction to the ferrous state. And in the third place, the sea water possesses so much Mg in the form of chloride and sulfate, that its capacity to leach out magnesium from such minerals as serpentine can be only

22. F. W. Clarke, Data of Geochemistry (1920), p. 527.

extremely small.

In contact with sea water, brown ferric oxide compounds will exhibit a tendency toward reduction, and when there are mixed gels of Fe_2O_3 and SiO_3, then these, together with the Mg of the sea water will readily serpentinize and thus go over into the greenish drab color.

The Ca from the augite, in so far as it is not or has not become leached out, however, will have been earlier converted into $CaCO_3$. Moreover, due to the high Mg content of the sea water which yields Mg, the latter takes place of the Ca, and $CaCO_3$ becomes more or less dolomitized.

* * * * *

6. Magnetic iron ore and titanium iron ore (magnetite and ilmenite).

In many respects these two constituents behave alike; as for example, in neutral or weakly alkaline water, in which they remain very resistant. Also CO_2 does not affect them. But now if organic materials, especially humic acids enter the picture, then the situation changes; the two minerals are attacked, magnetite earlier than ilmenite. FeO dissolves as carbonate or is oxidized to ferric hydroxide, and this latter then dissolves as a sol in the humic acid environment. The titanic acid from the ilmenite mostly remains behind. The result is then: a little, colorless titanic acid, mixed with silicic acid and kaolin.

Previously it was supposed that the red color of many kinds of tropical soils was to be ascribed to rusty, finely divided magnetic iron. Unaltered ore however is black, also finely subdivided. If it were rusty, then it should be brown. But the principal thing is that in a medium, which would allow brown or red iron ore to exist, magnetic iron is not attacked. Thus the red color is rather to be ascribed to iron oxide, originating from minerals such as biotite, hornblende, augite, hypersthene, and olivine.

In crater water, magnetic iron and titanium iron are entirely dissolved and leached out. An exception to this is the iron that in combination with the sulfur, originated from crater gas and crater water; this precipitates as iron pyrites and markasite. Even the titanic acid is not resistant in such an environment.

But also in sea water with its abundant Cl^- and SO_4^{--} ions, magnetite and ilmenite do not remain unattacked and, though it may be slowly, they go over into iron oxyhydrate, which is again immobilized in the form of serpentine-like minerals. Under these conditions the titanic acid usually goes over into titanite.

* * * * *

7. Apatite

In conclusion, a few words about this P compound which is present in small quantities in almost all rocks. Being a Ca-salt of a weak acid, it is relatively difficultly soluble in water, it is only slowly hydrolized in water, and in water with CO_2. Of course it is more rapidly hydrolized in acid weathering liquids. The calcium then goes into solution and leaves by one of the routes that has been stated above. The phosphorus, however, is preserved from more rapid washing out by its characteristic of being strongly fixed[23] by different soil constituents: by Fe_2O_3 and Al_2O_3 on the one hand, as well as by titanic acid and perhaps silicic acid on the other hand and, thirdly, by $CaCO_3$ and $MgCO_3$. --True kaolin and specific minerals do not appear to fix P. With a pH of 7 or higher the phosphorus is fixed by $CaCO_3$ and $MgCO_3$; this is a chemical process--not colloidal adsorption. With decreasing pH values down to 4, these carbonates fix less and less phosphorus since they themselves dissolve. Then that task is taken over by Fe_2O_3 and Al_2O_3, the oxides which (as hydroxides) in that range of acidity are the most resistant. But whenever at the same time titanic acid is present in colloidal form, then it fixes that P in a form that is practically insoluble.[24]

23. Cf.: E. John Russel, Soil conditions and plant growth (1932), pp. 225-226.

24. A. C. De Jongh, The locking up of phosphate fertilizers in Java soils, Intern. Mitt. f. Bodenk., 4 (1914), pp. 32-45.

Moreover, it seems as if organic colloids in the soil can also fix P; but how they do that is still uncertain.

As was to be expected, P is leached out in crater water. Only if it is combined with TiO_2, does it remain resistant to HCl and H_2SO_4. In sea water calcium phosphate dissolves only very slowly.

* * * * *

8. Calcium carbonate

Calcium carbonate plays a part in soil formation, both in the form of crystallized calcareous spar (calcite) and of coralline lime, shells and foraminifera skeletons. The solubility in the different weathering liquids increases with the degree of acidity, that is, with a falling pH; CO_2 as well as humic acids have a strong solvent effect, so that in a soil which shows a pH of 4.5 or lower, no calcium carbonate is to be expected. The lime is more or less in equilibrium with alkaline sea water. That is, according to the conditions, $CaCO_3$ can either precipitate out from the water in the Ca depositing organisms, or it can be dissolved from them. For example, when calcareous shells sink in the ocean to great depths, as a result of increasing pressure they dissolve before they reach the bottom. On land, at least in almost the entire Netherlands Indies, the leaching out of $CaCO_3$ is the dominant process. The exceptions will be considered later.

* * * * *

This concludes the consideration of the chief minerals which play a role in soil formation. We may now follow what happens to the rocks under the different conditions in which they weather. But before that, as a transition of great importance for the Netherlands Indies, a little special attention will be given to:

Volcanic glass

Under this heading are included all the volcanic products which have not already been mentioned under one or the other of the preceding seven sections dealing with crystalline mineral forms. Such volcanic glass can, and also as a rule will, possess all the elements summed up above, but obviously in very different proportions. The composition now depends upon two main factors: (a) the composition of the original magma and (b) what has already solidified from that magma in crystalline form and thus has been separated from the original whole.

Relative to (a) there is to be retained the differentiation[25] of acid magma, with 65% or more SiO_2, and clearly basic magma with 52% or less SiO_2, and between these two, magmas of intermediate composition, with approximately 53-64% SiO_2.

Relative to (b) ordinarily magnetic iron, titanic iron and apatite belong to the first separation; then in the more acid plutonic rocks, in the granites for example, there follow the dark minerals mica, pyroxenes, amphibole, thereafter the feldspar steps in, and finally the quartz. But in some basic rocks, such as gabbros and diabases, with much calcium and little alkali, calcium-rich plagioclases separate out sooner than the pyroxenes; this is also the case with many basic eruptive rocks of the Netherlands Indies.

It is now evident that through a separation of the minerals containing iron, the glass remaining over becomes clearer and finally becomes colorless. If, however, much colorless plagioclase separates out, then the iron concentrates in the glass residue which thereby may become dark or even black.

Thus from an acid magma we have to expect a glass which is much richer in SiO_2 than the whole (mineral and glass). In the intermediate cases one many times obtains colorless glass with much magnetite dust in it, as well as pyroxenes and plagioclase; such a glass is also more acid than the whole. But with the basic magmas we find many cases of rapid flowing out or of explosive ejection, and consequently rapid congealing of glass, where only Ca-rich plagioclase has been separated. And, since

25. Cf. pp. 8 and 17 in the chapter: Parent Material.

the plagioclase also varies greatly in its SiO_2 content, such glass is then practically as rich in SiO_2 as the whole. The glass is, however, much richer in iron than the original magma was.

Such black, iron-rich glass is much more easily attacked by the weathering liquids than is white glass, but one must not lose sight of the fact that the physical condition of the glass (whether as a homogeneous solid, in large blocks; or full of bubbles or air bells, non-homogeneous with strains, or in the form of gravel, sand or fine dust) has a predominating influence upon the time required for the weathering.

Now the chemical result, except for that dependent upon the weathering liquid, will depend upon what is present in the glass. Depending upon the conditions of degree of acidity and the nature of this liquid, the different bases will or will not be leached out; the same applies to the silicic acid. Particular attention must however be given to one point.

For the granite it was stated that first the dark minerals separate out, then the feldspar, (which is an alkali feldspar) and finally the quartz as the residue. Now the question is, if, before the feldspar crystallized, feldspar nuclei (i.e. kaolin nuclei!) were formed, in the then still existing glass, which subsequently grouped themselves as crystals; or whether the so-called hypothetical nuclei first originated during and through the crystallizing. If the latter is the case, then the glass is, so long as it is glass, free from nuclei; in the former case, on the contrary, the glass may have possessed nuclei long before, even though they are not yet perceptible.

However, it has often been perceived that upon the weathering of acid colorless glass there is formed much highly plastic white clay, thus much kaolin, or at least kaolin-like minerals. This fact argues for a preformation of kaolin nuclei in the glass before the crystallization. Plastic clay is not formed from the black glass.

In order to give definite preference to the theory of the preformation of such nuclei there should, however, be first carried out, for example, a fractionated analysis according to van Bemmelen, on colorless acid glass and on black basic glass, both free from crystals and then finely powdered. The white acid glass should give a considerable quantity, the black glass on the contrary, only an unimportant quantity of the so-called silicate B (soluble in conc. H_2SO_4).

In the weathering of natural glass there is found one peculiarity of which there was no need to speak in connection with the preceding minerals. For the course of the weathering it is very important, whether the glass is exposed to weathering in a completely massive and compact form, as obsidian or peckstone, or as a porous mass, as ash or pumice. The difference in attackable surface is extraordinarily great and owing to this a fine ash, for example, can be thoroughly weathered during a time in which the weathering of large obsidian blocks or glassy lava streams has not penetrated more than a few mm. deep. What that difference signifies for soil formation--a difference which likewise may be established in the weathering of thick plutonic rocks as granite and diabase as contrasted with the porous rocks as tuffs and limestones,--will presently be spoken of more in detail under the heading of "erosion."

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§2. A FEW EXAMPLES OF WEATHERING OF ROCKS

In connection with what was said concerning the weathering of the separate mineral constituents of the rocks, we can trace what must happen to a few main types of rocks of the Netherlands Indies, under the influence of the repeatedly mentioned series of seven different weathering liquids. Along with these, observations made in the field, as well as analyses carried out in the laboratory, will be presented in substantiation or correction of what was said.

We choose as the first type:

<u>Basic volcanic material (andesitic ash).</u>

In order to deal with generalities, let us start with a <u>lahar</u> (mud flow) consisting of fine ash, sand, gravel, and

stones up to blocks of a cubic meter. With an average content of SiO_2 of about 55%, practically all the minerals considered in the previous sections may occur in this mass. If the weathering is commenced by pure water, for example in a very rainy climate with a temperature above 25°C., then at once hydrolysis sets in. It is immediately obvious that the material most attacked is the finest ash with the greatest surface. Out of the glass, out of the feldspars, out of the dark minerals go Ca, Na, K, Mg as ions in solution; the reaction of the water becomes alkaline, the pH rises above 7. Also silicic acid which has been liberated goes into solution. Carbonic acid, present in the rain water, is instantly combined in the alkaline liquid; close to the surface one may even expect CO_2 absorption from the atmosphere. In the beginning, there is such a large quantity of bases in proportion to the small amount of CO_2, that carbonates are formed, through which the pH again can fall to 7 and below. In relation to liberated iron in the ferrous state, oxygen is present in excess, so that the iron can oxidize to ferric hydroxide, which remains behind as a gel. From the alkali feldspar, kaolin certainly remains behind as a gel; from the Ca-feldspar, less certainly, aluminum hydroxide remains which crystallizes as hydrargillite. The same occurs with the Al_2O_3 from the pyroxenes and the hornblende. Magnetite and titanium iron remain behind unchanged, just as do sporadic quartz grains, if any.

So the result to be expected is this: in the liquid relatively much Ca, Na, and SiO_2, less Mg and K; in the residue kaolin, which in turn holds absorptively K and Ca. All the Al_2O_3 and also the Fe_2O_3 are in the residue, in addition to the ore grains. Free SiO_2 was also present in the beginning.

And now how to verify this? --Certainly this is not simple, since nature is not a laboratory, where at one's pleasure definite conditions without disturbing side influences can be maintained. For example, the rain water is never free from carbonic acid; but, what is more serious, the land as it is thought of here, never remains free from vegetation, so that the natural water, which sinks into the soil, almost always possesses quite a little organic matter beside important quantities of CO_2.

We can now attack the question from two angles; from the point of view of the extractive liquid flowing out and from the point of view of the extracted residue remaining behind. It is very difficult to determine, by technical analysis, what small changes have taken place. Spring water, coming out from layers of fresh or only very slightly weathered lahar material, will not differ much in composition from the above-described weathering liquid. A number of analyses of spring waters are now available and since it is true they were not made with the purpose that we here have in mind, in various respects they are incomplete; however we must row with the oars which we have.

From among the analyses of drinking water published by C. P. Mom[26] those were selected which were of spring water originating exclusively from young volcanic lahar material (andesitic gravel). The results are found together in the following synopsis (Table 40, page 91, wherein all amounts are expressed in milligrams per liter, m/l).

If these figures are mutually compared, then it strikes one that they agree very closely. The residue after evaporation lies between 130 and 200 m/l and, in general is lower in rainy, moist West Java than in East Java. The silicic acid is always a sizeable part of the residue (see Table 40): 36-56 m/l.--Sulfuric acid is absent. It is very likely that it was present in the lahar material at the very beginning of the weathering. Then from these analyses it appears that sulfur disappears before other constituents. Chlorine seems to be present somewhat longer; perhaps additional chlorine comes down with the rain. Carbonic acid is an important constituent; all the regions are then green with vegetation. CO_2 occurs in the free form as well as in the bicarbonate form. The free form, from 12 to 44 m/l; as HCO_2 from 67 to 122 m/l. Over this range, the pH drops from 6.7 to 5.9. Calcium and Mg, are not able to combine with all the HCO_3; the rest combines with the alkalies, K and

26. Jaarverslagen v/h Proefst. v. Waterzuiv. Manggarai (bij Batavia) over 1928 t/m 1931.

Table 40

ANALYSES OF SPRING WATERS ORIGINATING FROM YOUNG VOLCANIC MATERIALS

Name of the spring	Kota Batoe			Tjiomas		Tjigoöng	?	Bajongbong	? On Mt: Oengaran	Woeling and Kalengan	Sb. Sari and Karangan	Oemboelan
For the water works of	Buitenzorg			Batavia		Poerwakarta	Tjiandjoer	Garoet	Semarang	Magelang	Malang	Pasoeroean
Analyses Jaarv. Manggarai:	I 1928 p. 8	II 1928 p. 8	III 1929 p.12	I 1929 p. 11	II 1930 p. 17	1931 p. 19	1929 p. 18 milligrams	1929 p. 13 per liter	1929 p. 16	1929 p. 13	1929 p. 14	1929 p. 15
1) Dry residue.......	132	140	140	154	151	140	160	162	164	172	196	180
2) Residue after ignition..........	112	112	120	134	125	121	138	132	136	144	172	158
3) SiO_2.............	46	55	52	46	36	40	54	40	52	56	46	48
4) SO_4	0	0	0	trace	0	0	0	0	0	0	0	0
5) Cl	trace	trace	trace	trace	trace	trace	trace	trace	0	---	trace	trace
6) CO_2	12.4	14.3	16.5	20.7	28.8	44.0	17.2	38.2	23.3	27.7	41.4	17.8
7) HCO_3.............	72.5	70.0	68.0	75.7	81.0	67.0	97.6	91.5	97.6	104.9	122.0	122.0
8) Ca	9.7	10.3	9.2	9.2	13.2	11.2	20.0	14.0	15.2	14.0	22.0	19.6
9) Mg	trace	trace	2.6	5.7	5.0	trace	trace	7.0	5.2	6.8	8.3	8.7
10) Fe	0.05	0	0.04	0.06	0	0	0.05	0.05	0.08	0.04	0.04	0.02
11) Mn	0	0	0	0	0	0	0	0.05	0	0	0	0
12) Organic matter.... ($KMnO_4$)	0.22	0.44	0.16	1.26	1.00	2.75	1.26	0.30	1.26	0.16	1.58	0.30
13) NH_3	0.02	0.03	0.02	0.02	0.04	trace	0.05	0.02	---	0	0.04	0.04
14) Protein-NH_3	0	0	0.01	0	0	0.07	0.02	0	trace	trace	0	0
15) NO_2	0	0	0	0	0	0	0	0	---	0	0	trace
16) NO_3	0	0	0	0.1	0.4	0.2	0	2.4	0.4	7	9	1.5
17) pH	6.55	6.5	6.4	6.5	6.7	5.9	6.7	6.2	6.1	6.1	6.2	6.7
18) Residue after ignition--(3+8+9)...	56	47	56	72	72	70	66	71	64	67	96	82
19) Na calculated from 7, 8 and 9...	16.2	14.6	10.1	7.0	5.8	12.4	13.8	5.0	9.4	10.4	4.8	6.8
20) CO_3 calculated from 7...........	35.7	34.5	33.4	37.2	39.8	32.9	48.0	45.0	48.0	51.6	60.0	60.0
21) 18 - (19 + 20)....	4	-2	13	29	26	25	4	21	7	5	31	15

Na (not determined). Calculated as Na, the amounts should be those shown in line 19, if a part of it is K then the amounts would be somewhat higher. If we accept as an hypothesis that the residue after ignition has been but weakly ignited, and that besides free SiO_2, Ca, Mg and Na are present as neutral carbonates, then they require the quantities of CO_3 stated in line 20. Then, however, according to line 21, there still remains after ignition an average residue of 15 m/l; this can be nothing else but alkalies. So we come to the conclusion that the principal constituent of the weathering extract is $NaHCO_3$.

The remaining constituents are negligibly small. Iron is not more than a mere 1/100 m/l, there is no manganese. The organic matter, determined by oxidation with $KMnO_4$, in only one case is above 2 m/l; ammonia is also only 0.03 m/l. These traces do not, however, detract from the main point, which is this: the constituents which one expected to dissolve are present in the solution, and those which one expected to remain behind (Al_2O_3, Fe_2O_3, Mn, Ti) do remain behind.

* * * * *

If one wishes to know what has happened in the weathering of an andesitic rock by much water, with sufficient CO_2 so that the pH remains between 6 and 7, the customary way is to carry out analyses of the fresh rock, as well as of the weathering mass, and calculate the percentage composition of both and then compare those two columns of figures with each other. However, this cannot be called anything but inadequate; the two totals, the 100%, never tally with each other, for when one is dealing with a continuous washing out process, there can never remain over just 100% of the original 100%, but only less, for example 60%. If, in addition to the eluvial processes, illuvial processes take place, then the 60% may again increase to 90% or even 110%. It would be only by a very rare accident, that exactly 100% were reached--an accident upon which one certainly should not depend.

The only possibility of exact comparison is that of equal volumes of weathered and unweathered material, provided one is certain that through the weathering the volume has not been notably decreased or increased. This possibility has been sometimes offered us by nature.

In the year 1909 I published some research[27] upon rocks from a one-time lahar from the volcano Boerangrang, northwest from Bandoeng. Those rocks consisted of a rock nucleus and a weathered crust, which belonged to it. After the surrounding loose soil was washed off, it appeared:

1. that the stone kernel and weathering crust without any doubt belonged together; the crust had been once entirely the same rock as the kernel.
2. the crust was fully weathered out; of the original rock no mineral grains other than the (iron) ore grains could be found;
3. the rock kernel was still almost entirely unattacked and unweathered, and
4. the transition from crust to kernel was very sharp, within 0.3 mm.

This beautiful material was investigated petrographically as well as chemically. The petrographic research showed that the stone kernel was a simple andesitic rock, entirely compact and with what (under the microscope) appeared to the eye as an entirely crystallized ground mass. The mineralogical composition appeared to be about the same as that of the porphyritic first generation, which gradually went over into the second generation. That composition is: a) plagioclase, brighter, without zonal structure of any significance, labradorite according to the optical characteristics; b) layer-like augite, no hypersthene; c) magnetite and ilmenite, partly as octaeders, partly as fine material which was difficult to determine; d) some brown very widespread weathering products, which perhaps had once been olivine. --Hence the rock appeared to be an augite-andesite quite close to basalt.

From the crust, thin sections were

27. E. C. J. Mohr, Ueber gelben Laterit und sein Muttergestein, Bull. Dépt. Agric. Ind. Néerl., No. XXVIII (Géol. Agron. No. IV).

also prepared, even a few slides of crust and kernel together; technically this was not easy, but yet we succeeded. (a) No feldspar was found in the crust; but the shapes of the crystals had remained fully preserved, so that the angles could be measured and therewith the labradorite forms verified. In the place of the feldspar small, colorless crystals forming rosettes could be observed; these had apparently grown like a ruffle trimming from the surface and from the crevices of the feldspar without, however, filling the whole space. Optically they were determined as "apparently hydrargillite"; some characteristics agreed well, others not entirely; both the n, as well as the $\gamma - \alpha$ reminded one frequently of the scales of kaolinite. (b) In the places of the augite crystals, also recognizable from the crystal form, lay a brown, amorphous iron hydroxide gel, that very possibly also included Al_2O_3 gel and SiO_2 gel. Of this material there was not enough to study optically. (c) The (iron) ore lay unaltered in between the other constituents.

In a now well established hypothesis from one volume of stone kernel there forms one volume of crust. It was thus desirable to determine the weight per cubic cm. of stone kernel and weathered crust. For the compact rock the volume weight equaled the specific weight, which was 2.772. With much care rectangular blocks were filed from the crust. After measuring the length, breadth, and height of these blocks, the volumes were determined; these, divided into the weight gave the volume weight, 1.50. Since the filings gave a specific weight amounting to 2.53, the crust appeared to consist of 3/5 solid material and 2/5 air.

The chemical analyses are presented in Table 41:

Table 41

ANALYSES OF ROCK AND WEATHERING PRODUCTS FROM IT

Constituents	Rock Kernel				Weathering crust			
	% of the preparation	% of the dry matter	mgr. per cm.^{3}	millimol per cm.^{3}	% of the preparation	% of the dry matter	mgr. per cm.^{3}	millimol per cm.^{3}
Water-100°	0.84	---	---	---	2.63	---	---	---
" -100-200°	0.06	00.59	16	0.83	0.91	22.24	334	18.51
" above 200°	0.52				20.74			
SiO_2	52.89	53.34	1478	24.52	15.43	15.85	232	3.94
TiO_2	0.96	0.97	27	0.34	1.82	1.87	28	0.35
Al_2O_3	18.93	19.09	529	5.18	38.57	39.61	594	5.81
Fe_2O_3	4.06	4.09	113	0.71	14.82	15.22	228	1.43
FeO	4.80	4.84	134	1.86	1.89	1.94	29	0.40
MnO	0.43	0.43	12	0.17	0.22	0.23	3	0.05
MgO	3.72	3.75	104	2.58	0.41	0.42	6	0.16
CaO	8.56	8.63	239	4.26	0.19	0.19	3	0.05
Na_2O	3.98	4.01	111	1.79	0.78	0.80	12	0.19
K_2O	0.94	0.95	26	0.28	0.08	0.08	1	0.01
CO_2	0.10	0.10	3	0.07	0.52	0.53	8	0.18
P_2O_5	0.22	0.22	6	0.04	0.35	0.36	5	0.04
Cl	trace	trace	---	---	trace	trace	---	---
SO_3	0	---	---	---	0	---	---	---
S	0.04	0.04	1	0.03	0	---	---	---
Total	101.05	101.05	2799	---	99.36	99.34	1481	---

Upon considering Table 41 one is immediately struck by the almost quantitative disappearance of calcium and potassium, and also of a great deal of the magnesium and sodium; besides, much SiO_2 is removed, but not all of it. Of the FeO a part is oxidized, but nothing washed out, for:

$$\frac{1.86}{2} + 0.71 = 1.64 \text{ and } \frac{0.40}{2} + 1.43$$

$$= 1.63 \text{ millimol. } Fe_2O_3.$$

In addition TiO_2 has remained behind, so has P_2O_5. Thus the following mineral composition may be calculated for the rocks:

1.79	millimol.	sodium feldspar	together forming plagioclase.
0.28	"	potassium "	
3.11	"	calcium "	
0.95	"	$CaO.SiO_2$	together forming augite;
0.965	"	$FeO.SiO_2$	
0.17	"	$MgO.SiO_2$	
2.58	"	$MgO.SiO_2$	
0.20	"	ilmenite	
0.07	"	calcite	
0.04	"	apatite	
0.015	"	pyrite	

and there still remain over: 0.83 m.mol. H_2O--1.215 m.mol. SiO_2--0.695 m.mol. Fe_2O_3 and 0.14 m.mol. TiO_2. If these last were also present as ilmenite, they should have been found afterwards in the crust, but for this there is an inadequate amount of FeO present therein; so presumably the augite is titanium-containing, and it possesses also some Fe_2O_3 and then, at the same time, the SiO_2 residue becomes smaller.

For the crust we find the following mineral composition

1.97	millimol.	kaolinite	$= Al_2O_3.\ 2\ SiO_2.\ 2\ H_2O$
3.84	"	hydrargillite	$= Al_2O_3.\ 3\ H_2O$
1.43	"	brown iron ore	$= Fe_2O_3.$ about $2\ H_2O$
0.20	"	ilmenite	

and then there remain over: 0.19 m.mol. H_2O,--0.15 m.mol. TiO_2,--0.16 m.mol. MgO, --0.05 m.mol. CaO,--0.01 m.mol. K_2O,--0.19 m.mol. Na_2O,--0.18 m.mol. CO_2 and 0.04 m.mol. P_2O_5. To group these constituents into definite minerals, which microscopically I could not detect, would certainly have been too speculative. Moreover, different bases were most probably bound adsorptively on the kaolin, while P_2O_5 was combined with TiO_2 and Fe_2O_3.

Why the Al_2O_3 content per $cm.^3$ crust appears so much higher than that of the rock kernel cannot be explained. It can, in part, be laid to imperfections in the analysis, but this is not deemed very probable. It may also be due to the heterogeneity of the material, a factor which can never be entirely excluded. However, if this is accepted, we admit the impossibility of making comparisons. Meanwhile the following is presented:

According to the above-developed consideration relating to weathering, 1.79 + 0.28 = 2.07 m.mol. alkali feldspar of the stone kernel should leave behind 2.07 m.mol. kaolin. It may be somewhat less, for the kaolin is washed out a long time after the SiO_2. In the crust are found 1.97 x 2 m.mol. SiO_2.

The 3.11 m.mol. Ca feldspar should leave behind as much Al_2O_3 as hydroxide, and no SiO_2. The 3.84 m.mol. Al_2O_3 which were found, is 0.73 m.mol. too much; but the crust has also in total a surplus of 5.81 - 5.18 = 0.63 m.mol.--The results do not come out definitely but still they incline in the direction of the hypothesis; at least they are not in contradiction to it. For example, in case the calcium feldspar also gave kaolin, one should have found (2.07 + 3.11) x 2 = 10.36 m.mol. SiO_2 in place of 3.94; that difference is too great. And likewise if the alkali feldspar is completely split up into alkali in solution, SiO_2 gel and Al_2O_3 gel,--as is still quite generally accepted[28];--then why should 3.94 m.mol. of the 24.52 SiO_2 remain over?

* * * * *

As a second example of a weathered rock the silicic acid-rich liparitic ash which contributes so mightily to soil formation in various parts of Sumatra, will here serve the purpose.

28. Compare what has been said already about this on page 78.

The feldspar, in part sanidine (potassium feldspar), in part plagioclase (oligoclase) with much Na and little Ca, weathers relatively slowly. The sanidine weathers somewhat sooner than the plagioclase; the rates of weathering are apparently related to the crystallization. The plagioclase consists of water-clear, hard, homogenous crystals, while the sanidine is more contaminated and is more zonally built up, so that it can take up more water in weathering. However, whenever these two minerals weather in the presence of much water plus more or less carbonic acid, then they supply K and Na ions to the liquid, besides SiO_2 in the sol form, and leave behind considerable kaolin.

Neither augite nor hypersthene occurs in it; the (little) hornblende supplies some Mg, Ca, and Fe'' ions to the liquid, also some Na. But after oxidation, the ferrous iron precipitates again as ferric hydroxide; also the Al_2O_3 remains behind as the hydrated gel. But the SiO_2 follows rapidly into solution the cations which have already gone.

The weathering of the biotite (iron-magnesia-mica) is slow, but it results in kaolin with some iron oxyhydrate (clay) and the Mg dissolves but very gradually. --Iron ore is essentially never present.

The principal mass, with the feldspar and the unaltered, bright quartz is however the pale glass, mostly finely divided as pumice and ash. This glass weathers very rapidly, more rapidly than all the included minerals. It gives up to the weathering solution alkalies and SiO_2, but almost no Ca nor Mg, and leaves behind much pale kaolin, poor in iron.

Adding all this together then, the solution in comparison with that coming from the basic andesitic ash is much poorer in Ca and Mg; also the concentration of the alkalies must be less, since the weathering progresses more slowly. What remains behind will be relatively richer in kaolin, poorer in Fe_2O_3 and Al_2O_3, the last two occurring in the form of hydroxides.

As far as the weathering liquid is concerned, some figures are available in the data of Mom.[29]

a. The water of the spring Taroetoeng at Balige contained, besides "traces" of Ca and Mg, 33 m/l silicic acid and 36.6 m/l HCO_3, combined with alkalies, (if all as Na: 13.8 m/l, if all as K: 23.7 m/l, actually an intermediate amount). Fe,--Mn,--SO_4 and Cl were absent.

b. A spring near Bangoen Poerba also contained only traces of Ca and Mg, as also of Cl; Fe,--Mn,--SO_4 were absent. --SiO_2 was higher: 72.4 m/l--For the 61.0 m/l HCO_3 there may be calculated 23 m/l Na or 39 m/l K; also here there has most likely been present a mixture of Na and K.

When considering irrigation water (in a subsequent section, under "Irrigation") still more examples which are in entire accord with the above will be mentioned.

* * * * *

As a third example, it would be very interesting to discuss a granite, consisting exclusively of Ca-free potassium feldspar (orthoclase), potassium mica (muscovite), and quartz. Now if the general considerations of the weathering by pure water plus carbonic acid be correct, there will remain over only kaolin plus quartz; potassium and silicic acid go into solution. In each case no free Al_2O_3 hydrate remains over nor is present in the solution. Unfortunately there are no data available in the Netherlands Indies regarding such a granite, nor of any spring water which flows out from such a granite terrain; all the granites that occur there possess at least some Ca in their feldspar or at least some dark minerals such as biotite, and hornblende! From the Ca feldspar and the hornblende Al_2O_3 can remain over; from the biotite and the hornblende Fe_2O_3 and some Mg, which however becomes washed out.

From this it follows that under the conditions here referred to, the weathering mass resulting would be completely free from Al_2O_3 hydrate gel; but such a condition is seldom to be found, since the rocks which possess Al_2O_3 exclusively in the form of alkali feldspar and potassium mica are so infrequent. In the cases where Ca-

29. L. c., Jaarversl. (1929), p. 23, and 1931, p. 10.

feldspar and other, dark, Al-containing minerals occur only in small amounts in the rocks, a small content of Al_2O_3 in the weathering product can easily escape the attention. In this connection it is indeed noteworthy what J. B. Scrivenor, the experienced specialist in the geology of Malaya, writes on the subject:[30]

> "In Malaya, in Indo-China and in the Netherlands Indies the change in 'acid', granite rocks, which have a high percentage of silica, does not go beyond the formation of hydrous silicate of alumina, except perhaps for a small portion hard to prove; and therefore the soil is clayey owing to the presence of kaolinite and perhaps halloysite. In less acid, or 'basic' rocks on the other hand, when weathered, there is an appreciable amount of aluminum hydrate;...."

This statement agrees entirely with our experience in the Netherlands Indies. The opinion of J. B. Harrison[31] who had been so many years in the British West Indies, in particular in Barbados and in British Guiana, also agrees with that.

It is indeed unfortunate that in the data of C. P. Mom there is none relating to springs in any of the Netherlands Indies granitic tracts. As long as the hiatus exists, we will have to get along with figures relating to surface water (rivers and creeks) originating in granitic regions.[32] In these data the SiO_2 content varies from 0 to 8 m/l, the HCO_3 content from 6 to 30 m/l, the Fe content from 0 to 0.6 m/l. --"Poor in all constituents" is indeed the characteristic of such water from granitic tracts; besides, if they are not contaminated by human settlements, the total "residue after ignition" of these waters varies between 6 and 25 m/l. It is meanwhile possible and even probable that spring waters, making their appearance from deeper, less weathered out layers, contain significantly more dissolved constituents.

Data from Surinam[33] relating to borings in presumably secondary deposits from and on granitic terrain, with a low chlorine content, and hence little mixing with sea water, show the following figures: Cl. 3.9-4.7 m/l, SiO_2 1.5-7.5 m/l, Fe: 0-0.6 m/l, Ca 0.25-0.8 m/l. Frequently from borings, water is obtained with less than 30 m/l dry residue, and less than 25 m/l residue after ignition. These figures are of quite the same order as those from the Netherlands Indies granitic tracts.

* * * * *

§ 3. THE SOIL AND LIFE

From consideration of all these natural waters as weathering liquids it appears that at one instant they act as agents of weathering and at the next as the result of weathering, and again a moment later again act as weathering agents. Thus the agent meanwhile continually changes, but in the long run the original agent has the greatest influence.

This latter is however only true as long as the organic life on and in the soil can be left out of consideration; if it must be included, then the whole picture changes.

In order to make the first example clear, let us take up again the andesitic lahar (mud flow). Originally on and in the lahar there is no organic life, no flora and fauna neither on the lahar nor in it. The rain water that acts as the weathering agent is thus originally water with a little oxygen and carbonic acid dissolved in it. After the first onset of weathering, organic life originates on and in the soil, and therewith the active weathering agent changes, for at the same time with the commencement of organic life its decomposition and disappearance also

30. Malayan Agricultural Journal, 17 (1929), p. 458.
31. J. B. Harrison, Geol. Magaz., n.s., 7 (1910), pp. 439-488, and 553; Geol. Magaz., n.s., 8 (1911), pp. 120-353.
32. Cf. the water analyses in the frequently mentioned "Jaarverslagen Pr. st. v. Waterz.," (1928), Nos. 10 and 18; (1929), Nos. 7 and 12; (1930), No. 19; (1931), Nos. 19 and 29.
33. Dr. J. W. Jenny-Weyerman, 2 Rpt. over den Aanleg eener Waterl. te Paramaribo,--not for sale--. In it are analyses by Ir. J. W. van Dijk.

commences. Owing to this, all kinds of organic materials are supplied to the weathering liquid. These living organisms have taken up all sorts of constituents in the course of a long time, and when they die, these are again returned to the soil or to the water, but frequently in very different forms. If one makes up the final balance sheet, then the end result is: a continuous fixing of carbon and nitrogen in countless forms and combinations in the soil and in the soil water. The most important of these effects of organic life, in particular of the above-ground flora, followed by that of the under-ground, is the concentration of carbonic acid out of the atmosphere and into the subterranean weathering liquid. Isn't it true that in rain water the CO_2 content is at most 2 to 3 m/l?[34] While in spring water coming from rocks which by virtue of their formation and nature do not already contain CO_2, in some 20 analyses the following amounts were found:

	Free CO_2	HCO_3	Total CO_2
Minimum..................	9	15	40 m/l
Maximum..................	80	128	126 "
Average of 20 analyses...	28	78	84 "

These quantities are 30 to 40 times as much as in the rain reaching the soil.

The organic matter, oxidizable by $KMnO_4$, in these spring waters is about 1 m/l, between the limits 0.25 and 1.3 m/l. It is obvious that in comparison with water and carbonic acid this organic matter can exercise only an insignificant influence. And the organic matter which is not attacked by $KMnO_4$, if present at all, will certainly be inactive.

* * * * *

The organic matter in the soil. Humus.

We now come to the discussion of the important role which the organic matter in the soil (as a rule designated by the one word humus) plays in weathering and soil formation.

To continue to deal with "organic matter" as a single sort of material is not correct. It is necessary to differentiate it into several fractions. It is true that it is not the intention here to expand this subject to the greatest extent; but yet some differentiation is still necessary.

Here the main separation is into dead and living organic matter; under the dead is included what falls upon the soil from the above-ground vegetation and which is taken up by the soil in one way or another; under the living are the soil flora and fauna, (though this latter, quantitatively as "matter," is of less importance).

With the former must be included the fallen leaves, fruits, branches, dead trunks and roots. These consist firstly of substances soluble in water, which may be divided into (a) the sugars, salts, etc., which are food substances easily taken up by the living soil flora and fauna, and (b) tannins and that sort of "more difficultly digestible" substances: and secondly (c) the celluloses and pentosans of the cell walls; (d) the difficultly attacked substances lignin and cutine, and--last but not least--(e) the nitrogen-containing proteins. They all together form the raw materials, which are imported into the "business" of the soil and then in the first place serve as food for the "workers" in that business the organisms in the soil.

These soil flora and fauna consist of countless sorts of organisms which may be collected into a few main groups:[35]
(a) bacteria, used in a general sense,
(b) molds, also used in a general sense,
and in addition a few groups of quantitatively less significance, such as

34. This amount applies to Central Europe; in the Netherlands Indies it will certainly not be higher but probably lower, because of the higher temperature. Analyses of rain water have not yet been published by the Royal Magnetic and Meteorological Observatory: CO_2 determinations of rain water presumably have never yet been made in the Netherlands Indies.

35. Cf.: E. John Russell, Soil conditions and plant growth (London, 1931), Ch. VI; A. Rippel, Niedere Pflanzen., Handbuch der Bodenlehre VII, p. 239; S. Waksman, Principles of soil microbiology (New York, 1927).

(c) algae, (d) myxomycetes, (e) actinomycetes, (f) protozoa (under which fall amebae), etc. They all live on the waste products of the above-ground flora and/or upon each other; but in such a way that CO_2 is always split off as the end product from the "business." This is the same carbonic acid that in the preceding pages was found in the soil moisture and in the spring waters.

If the addition of plant waste from above is suspended, then the life in the soil consumes the provisions present and finally consumes itself, until all "organic matter," and all "humus" are mineralized. While this is something which will seldom occur in Central Europe; in the Netherlands Indies circumstances arise which cause a very close approach to complete mineralization.

If anywhere the supply of plant waste upon and in the soil is so great that the soil organisms cannot completely work it up, then the provisions increase, and the dead and living "organic matter" accumulate and we are concerned with increasing humus formations, i.e. different forms of "peat." This last can be the consequence of two causes: (1) too great an addition of plant wastes, a case which practically never occurs; and (2) circumstances which inhibit the soil organisms in their activities; this condition may come about in different ways.

One must still always keep in mind that with reference to temperature and moisture all living organisms are confined within definite limits:--not all groups within the same limits, but still within limits. One can think of an imaginable hinderance to life, a poison, for the soil flora which might not similarly affect the flora upon the soil; such a case would lead to an indefinite accumulation of plant remains. If the mineralization keeps step with the humification, then there will never be any humus accumulation. But this last does not say that in the uppermost layers of the soil as a whole no organic matter occurs; of course there is some organic matter in the soil, in the form of the soil flora as consumer, and in the form of non-altered, slightly altered, or much-altered plant residues as food for the soil organisms. If, however, the activity of the latter is very intensive in comparison with the addition of material from above, then the humous soil layer can be only very thin. If the activity of the soil micro-organisms is weaker, however, then the organic matter must obviously be multiplied into a thick layer. As the concentration of consumable humus becomes greater, the number of consumers increases. The condition always remains in equilibrium; from above there continually come plant remains, from below there flows out water containing carbonic acid but without dead or living organic matter. Except when the organisms (even with a greater thickness of the layer wherein they can work, and relatively favorable conditions for the mineralization) cannot keep up with the supply, then the accumulation commences (peat). The outflowing water contains carbonic acid and undecomposed organic substances which give it a dark color. ("ajer hitam" Malay).

The addition of plant remains and the living conditions of the soil organisms determine which condition will prevail.

The formation of "organic matter"--Humification.

The quantity of plant remains from the above-ground vegetation depends of course upon the intensity of the vegetation, which deposits its residues on the ground.[36] The main factor for the formation of organic matter by vegetation is the direct, and also the indirect radiation from the sun. Without light there can be no assimilation of the carbonic acid of the air. The total illumination of the whole year, while the smallest at the poles, is the greatest at the equator. But the relation between illumination and latitude is not such that it proportionally decreases with increase of latitude; this appears clearly from the following data.

The quantity of energy, expressed in calories per sq. cm. per day, "radiated" by the sun toward the earth, is called the

36. Subjects such as burning of forest, grass fires, the removal of hay and cereal crops, weeding, clearing, etc., will be considered elsewhere in this publication.

solar constant; this amounts to about[37] 2 cal./cm.^{2}/min., when striking the surface perpendicularly. But not all of the two calories reaches the surface of the earth.

A part of that radiant energy becomes directly absorbed by the atmosphere. In the high layers of the air, at about 50 km. altitude, the ozone that is present eliminates a greater part of the ultraviolet rays with a wave length of less than 0.3µ[38]; quantitatively however that is but a very small part of the total radiant energy. Much greater is the absorption in the lower atmosphere of the rays of the remaining part of the spectrum; so Boerema records[39] that with a 60° elevation of the sun, the total radiation reaching the earth amounts to:

On the Smeroe	3670 m.	elevation	1.7	calories (approx.)
" " Pangeranggo	3020 m.	"	1.65	calories
At Tjisoeroepan	1200 m.	"	1.45	"
At Batavia	10 m.	"	1.25	"

In August and September the last named figure for Batavia falls to 1.13 calories, while in December to May it rises to about 1.30 calories. This already indicates that the condition of the atmosphere has a marked influence; in the dry east monsoon, for example, small particles of dust forming dry haze have a scattering effect; rain purifies the air, so that much rain, as during the wet west monsoon, permits strong radiation in the hours of sunshine which lie between the showers. But the water vapor also has an absorbing effect. The mountain tops have high radiant energy, where there is always only a little dust in the air. In the west monsoon there is less radiant energy than is measured in the dry monsoon.

In addition to the absorption, consideration must also be given to the scattering of the rays in the atmosphere, owing to which a large part of the direct rays are lost. Since diffusion takes place in all directions, while half go upwards into the expanse of the heavens, the other half go downwards toward the earth. These latter rays coming to the earth as the so-called diffused light or sky radiation, are useful.

Absorption and scattering are however not equally strong for all kinds of rays; the composition of the whole radiation thus becomes modified in passing through the atmosphere. The absorption is relatively greater for the rays of longer wave length (red and infra red) than for those of short wave length (violet and ultra violet); but the scattering acts much stronger in the opposite sense, since rays of greater wave length are less scattered than those of shorter wave length. Therefore the color of the rising and setting sun is red, because of the longer distance that these rays must then traverse through the lowest layers of the atmosphere, while on the other hand the scattered, diffuse radiation, the light of the heavens (sky light) is blue to violet.

The higher one goes in the atmosphere, the less scattering, and the less sky radiation. Thus in the Netherlands Indies it has been found that the sky radiation was the greatest at Batavia, less at Tjibodas, and still less on the top of the Pangeranggo; at each of these places the sky radiation was the least when the sun was highest. When the sun was lower, sky radiation can become as great as the direct radiation from the sun.[40]

In addition to what has already been mentioned, still another phenomenon should be recorded. The atmosphere, as has been said, through absorption retains as heat a part of the energy of the sun's radiation. All this heat collected in this way by the atmosphere is, for the greater part, radiated at all angles in the form of (dark) heat rays; so that each air particle is then a separate center of radiation. The combined result is that a great deal of this dark heat radiation is lost upwards into the outer space about the world. However the other large part is directed downwards toward the earth. This latter is called the counter radiation

37. K. Knock, Klimafaktoren der Erde, Handbuch der Bodenlehre II, p. 5-7; J. Schubert, Klima d. Bodenoberfl. etc., Handbuch der Bodenlehre II, p. 54-57.
38. M. P. Vrij, Vergel, metingen v. ultrav. zonnestr. i/d tropen en in Europa, (Diss. Amst., 1932), p. 1-10.
39. J. Boerema, Intensiteit der zonnestraling, Hand. 1e Ned.-Ind. Natuurw. Congr. (1919), p. 99-101.
40. Vrij, l. c., p. 58.

which, with the increase of the latitude of the earth, plays an increasing part with respect to the temperature of the earth's surface.

So then, when the conception "the" radiation of the surface of the earth is placed under the magnifying glass it is apparent there is active a whole complex of radiation phenomena; and all components of that complex are in their way important for the vegetation.

Although today we must still admit that we do not know very much about the quantitative influence of all these separate components upon plant production, yet of each influence in itself, it certainly may be said that in each moment it is dependent upon--though that is not saying directly proportional to--the intensity of the radiation and its duration.

The intensity however varies from moment to moment, with the angle at which the direct rays of the sun fall, with the condition of the atmosphere, and with the cloudiness.

The total production of vegetative matter per day or per year or per vegetative period then becomes a summation of the products of all those moments, which together make up the day or the year or the selected vegetation period.

If we first exclude the cloudiness and then put all other forms of radiation into terms of heat, the following table gives a picture of the total radiated energy from the sun to the earth, calculated in averages per day[41] (see Table 42).

From this Table 42 it appears that at all higher latitudes than at the equator days occur which receive a higher total daily radiation than at the equator. But as a consequence of the absorption, scattering, reverse radiation, and cloudiness, how much of the total radiation actually reaches the surface of the earth is quite another question. It would be fine if one could state in figures the influence of all those factors for the radiation of different wave lengths; such as for the ultraviolet rays, for the radiation from violet to red, for the infra red rays. Such figures are however not available, in part at least because they are most extremely difficult to determine. One must be content with very rough estimates.

Thus Knoch[42] recorded as rough, average approximations that the absorption may be considered to be 20% of the radiation. Approximately 36% is scattered; 18% goes upward and is lost from the earth; while only 18% remains useful as diffuse radiation. The earth thus receives 44% direct and 18% indirect as sky radiation. This is with a clear sky; if the cloudiness averages 50%, then as a result of radiation from the upper surface of the clouds a half of the 44% is again lost into outer space. The earth thus receives but 22% + 18% = 40% of the energy which the sun radiates toward it, supposing

Table 42

RADIANT ENERGY RECEIVED AT DIFFERENT LATITUDES

	90° Pole	80°	70°	60°	50°	40°	30°	20°	10°	0° Equator	
Annual average per day.......	366	378	417	500	601	694	773	830	867	880	Cal/cm.^{2}
The summer maximum per day...	1103	1086	1038	1002	1015	1015	998	958	901	809	"
The winter maximum per day...	0	0	0	51	181	326	477	627	745	863	"

41. Knoch, l. c., p. 5.
42. Ibid., p. 6.

always that 18% diffuse radiation remains the same in spite of the cloudiness, which is not entirely correct. If however we accept the latter, then the earth would receive by direct and indirect radiation, (still without including the (dark) counter radiation) (see Table 43):

Table 43

with unclouded sky		62%	of what the sun sends toward the earth
"	80% sunshine	53%	" " " " " " " "
"	60% "	44.5%	" " " " " " " "
"	50% "	40%	" " " " " " " "
"	40% "	35.5%	" " " " " " " "
"	30% "	31%	" " " " " " " "
"	20% "	27%	" " " " " " " "

observations of the percentage of sunshine, according to which the average, yet with considerable variations, lies around 50%. There are some places (Pasoeroean, Asembagoes, Timorkoepang); where the figure approaches 80%; others where the total falls to less than 30% (Ngadawono); Batavia

We now make use of the data of Sv Arrhenius[43] and present it as Table 44:

stands in Braak's list with 68%; elsewhere[45] we find for that place a statement of an average of 2,326 sunshine hours per year;

Table 44

DIRECT AND INDIRECT RADIATION RECEIVED AT DIFFERENT LATITUDES

	60°	40°[1]	20°	0°
		N. Latitude		
The average percentage of sunshine amounts to............................	39%	51%	60%	42%
Then the earth's surface receives, according to the preceding table, only..................................	35%	40.5%	44.5%	36.5%
Of the energy radiating to it; and making use of the figures on page 100, the values become......................	175	281	370	321 cal/cm.^{2}/day

1. This figure is given as 20° in the original Nederlandsch text but it must be a typographical error for 40°. --Translator.

If the figures of Arrhenius are correct, the tropics of Cancer and Capricorn receive significantly more radiant energy than the equator.

In the Netherlands Indies, there have been made[44] a great number of

which would be 53% of the possible maximum of 4,400 sunshine hours.[46]

If we compare those 2,326 hours with the corresponding figures of 1,492 hours for de Bilt,[47] then it appears that the first mentioned number of hours is

43. Sv. Arrhenius, Phil. Mag., 41 (1896), p. 275. Refer. in: H. Lundegårdh, Klima u. Boden (1930), p. 11.
44. C. Braak, Klimaat v. Ned.-Indië I, afl. 4, p. 252-262.
45. M. P. Vrij, l. c., p. 58.
46. The difference between 68% and 53% may presumably be explained, since the first figure refers to the time of observation: 8 AM—4 PM, while the 4,400 hours are those between sunrise and sunset. Moreover, the two figures need not necessarily refer to the same years.
47. De Bilt is the central meteorological observatory for the Netherlands.

almost double that of the latter. Even with its many showers, the notorious climate of Buitenzorg has almost as many sunny hours as Batavia; so indeed the European coming from the Netherlands can speak of "sunny India"!

With 80% sunshine, as for example has been observed at Pasoeroean, the surface of the earth, according to the table on page 101, receives approximately 53% of the radiant energy of the sun. While with 30% sunshine at Ngadawono only about 31% of the radiant energy is received. Thus in the Netherlands Indies there are places which are close to each other, yet one receives but about 4/7 of the radiation of the other. It is apparent that with otherwise equal circumstances, this must affect assimilation and vegetative production. Yet little has been observed of this effect on the development of plant growth in general, since differences in the trend are obscured by the action of other factors. The principal opposing factor is no doubt that a high amount of sunshine is accompanied by drought, so that a lack of water more than nullifies the advantage of much radiation, arrests growth, and even leads to a fall of leaves as in teak forests. Then assimilation is, of course, entirely excluded. Where, however, in times of much sunshine man comes in and artificially by means of irrigation can abolish or prevent the lack of water, there the greater assimilation results in greater vegetative production.

According to the figures in Table 44 from Arrhenius, the lands along the tropics receive more radiation than those on the equator. If a deficiency of water could be eliminated we should in consequence expect a higher production of vegetable matter there than on the equator.

But in addition to the direct radiation the temperature also has a role to play in assimilation.

This influence of the temperature upon the assimilation is no doubt known from numerous scattered observations, but it is remarkable that experiments have almost never been carried out in the tropics or elsewhere in such a way that the results are of direct importance for the tropics.[48] Because presumably each kind of plant has its own maximum, minimum, and optimum temperatures, not alone for assimilation but also for respiration (which in a certain sense again partially breaks down the gain of organic matter) and for growth, it is very difficult without experiments to come to definite conclusions for a whole flora. Meanwhile, two rules appear to be indicated as being quite probable: (1) the optimum temperature for assimilation appears, with reference to respiration, to lie relatively low: seldom does it reach 30°C (and that only with a very high CO_2 content of the air), more often it is around 25 to 20°C; while (2) for respiration, in which the carbohydrates are again burned to CO_2 and water, the temperature optimum seems to lie much higher, even beyond the usually occurring temperature maxima of the air in the tropics, that is, approaching 50°C. --If these rules are generally applicable for tropical vegetation and conditions, then it follows that from the assimilation optimum upwards the materials formed by assimilation are to an increasing degree again consumed by respiration, and finally the carbohydrate reserves will be destroyed. Then the plant cannot grow any more, and it must finally be ruined, consuming itself in spite of the best soil and water conditions. Not often will it be so bad as all that; particularly as plants possess all kinds of adaptations, through which the temperature of its organs is lowered (leaf-position for example, of the Leguminosae; strong evaporation). Meanwhile it does appear that it is by no means necessary to accept that the greatest intensity of vegetative production on earth must lie at places with the highest radiation and the highest temperature;--on the contrary it is quite conceivable that along the tropics the temperature repeatedly rises so far above 30°C that the surplus of organic matter, above the quantity consumed by respiration, decreases significantly.

But then also at still higher latitudes, for example between 30 and 50° N and S Latitudes, with average temperatures of from 17° to 23°C the production can well be just as large as at the

48. Cf. Schimper, Pfl. geogr. auf physiol. Grundl. (1898), p. 53; idem., p. 233. Cf. Lundegårdh, l. c., p. 109-126.

equator at 25° to 27°C. And such conditions would also exist in the tropics at elevations of 1,000 m., for example, where temperatures of 19 to 21°C. prevail. On the grounds of what has been said above, there is no occasion to wonder about the fact that in the mountains of the Indies at such elevations there are sometimes just as heavy tropical rain forests as at sea level.

The peculiar difference between this production in the tropics and at higher latitudes is not a matter of maximum intensity, but of the duration, which is 12 months in the tropics, while less at higher latitudes. In the Netherlands it is as little as about 4 months, hardly longer than the trees, on the average remain in full leaf.

It is very doubtful if experimental determinations or exact calculations of the total production of organic matter per hectar in the tropics have ever been carried out. Thus Vageler[49] expresses himself very cautiously about this: "The yearly production of fresh organic matter in the primaeval forest approaches 100 tons per acre on a cautious estimate." (250 tons per hectar.)

How this amount was arrived at, together with the "approximately 50 tons" for the "monsoon forests," he has not stated. Regarding the savannas Vageler says:[50] "The savannahs in this sense are not far behind the monsoon forests in production of organic matter. A cautious estimate would put the production at about twelve tons per acre per year." (30 tons per hectar.)

For European trees, beech, spruce and fir, Ebermayer[51] stated that they all three per hectar per year produced approximately the same amount of dry organic matter, that is 6,278,--6,272 and 6,339 kg., or 6.3 tons. The total amount of "forest litter" falling from them he calculated at 4,066,--3,588 and 3,706 kg. or approximately 4 tons. If one compares the figures of these two investigators, then it is obviously necessary to accept in the "fresh organic matter" of Vageler a sizeable proportion of water.

However this may be, in each case from the tropics up to latitudes of 50 to 60°, it must be considered very desirable to obtain, according to uniform methods, figures of the maximum vegetative production of organic matter. Not alone for the scientific value of it, but also because of a question of a practical nature, namely in how far, in proportion as the earth becomes more densely populated, will the production of (usefull) organic matter be transfered more and more toward the equator.

* * * * *

The breaking down of "organic matter." (Mineralization).

It has been already mentioned above (page 102), that through the respiration of plants a large part of the substance formed goes back again into the air as CO_2 and water. This book is not the place in which to go farther into that; it is enough to remark that during warm nights with overcast sky this respiration must be significantly stronger than in the brighter cooler nights; this can be a reason why at one place in the tropics the plant's own consumption of elaborated materials is much greater than at another.

That respirational loss of organic matter, however, falls outside of the subject with which we are here concerned, namely the mineralization of the vegetative offal. This occurs:

1. in part, very slowly, directly; but,
2. predominantly very rapidly, indirectly, through the activity of decomposing organisms on and especially in the soil.

1. The direct mineralization (oxidation) of organic matter simply by the oxygen of the air without the assistance of organisms, is indeed accepted by many as a fact, but the necessary figures to prove it are not found in the Netherlands Indian literature; and as good as

49. P. Vageler, An introduction to tropical soils, translated by H. Greene (1933), p. 84.
50. Vageler, l. c., p. 90.
51. E. Ebermayer, Lehre v/d Waldstreu (1876), p. 68; Forstl. Naturw. Z. 1894.

not at all even in the European or American literature. For example, Robinson writes[52] in his book on soils: "Whilst purely chemical decompositions play a certain part in the decomposition of plant residues, particularly in tropical soils, these changes are mainly due to the activity of the soil fauna and flora." Then he continues to disucss the fauna and the flora, and the reader learns nothing more about the former question. Sir John Russell[53] in the latest edition of his book, in other respects so excellent and complete, does not even touch upon direct oxidation. Hall[54] goes even farther and definitely expresses himself negatively: "These changes (of the organic material), at one time regarded as purely chemical, are now recognized as dependent upon the vital processes of certain minute organisms, universally distributed throughout cultivated soil." Here there is no question of "both....and" but only of "either....or."

On the contrary Ludegårdh[55] in speaking of mineralization says: "In farm yard manure and urine there are various aromatic compounds which are strong plant poisons; but they disappear very rapidly in the soil." He implies that these "strong plant poisons" are also poisonous for the organisms living in the soil, and are not broken down by organisms, but simply in a chemical manner. Indeed, he continues as follows: "Not all processes of oxidation in the soil are biologically conditioned; a sterilized soil also slowly evolves carbonic acid. (cf. J. König and J. Hasenbäumer, Landw. Jahrb. 55 (1920), S. 200)."

In a compiled digest for reference König and Hasenbäumer state that A. Spieckermann and J. Westhues[56] sterilized a quantity of soil at 150°-172°C and thereafter at ordinary temperature found during 7 weeks a carbonic acid formation of:

61 mg.	per 500 gr.	sterilized soil		
179 mg.	per 500 gr.	sterilized soil	inoculated with	Bacillus racemosus
274 "	" 500 gr.	" "	inoculated with	Bacillus vulgatus
156 "	" 500 gr.	" "	inoculated with	Streptothrix chromogena

If we accept that apart from biological influences the inoculated soil also continued to produce CO_2, then the bacteria in this experiment did not produce more than three times the production of the sterilized soil, and that non-biological carbon dioxide production must be considered as a factor.

With this we have now come into the field of definite observations. It is certainly notable that most investigators who published observations regarding the biological production of carbonic acid by soil organisms, completely neglected this factor, not even mentioning a word about it and thus apparently *a priori* agree with Hall, as recorded above.

Now since it has appeared that through pure chemical action from plant remains and humus *in* the soil itself carbonic acid can develop, then one may still more expect similar production from similar kinds of offal *on* and *above* the surface of the soil, not alone because of the higher O_2 and lower CO_2 concentration in the atmosphere but especially because of the active rays therein.

The light rays are the most important, but a close second to them are certainly also the ultraviolet rays. It has been long presumed that in the tropics these penetrate through the atmosphere to the earth's surface to a lesser degree than in the cooler regions of the earth. That now appears to be incorrect.[57] What the "mineralizing effect" of those rays is, however, we do not know. Once again, actual evidence is not available; there are however indications as to the direction.

52. G. W. Robinson, Soils, their origin, constit. and classif. (London, 1932), p. 126.
53. E. John Russell, Soil conditions and plant growth (London, New York, 1932).
54. A. D. Hall, The soil (London, 1931), p. 213.
55. Ludegårdh, *l. c.*, p. 393.
56. See J. Westhues, Dissert. Münster i/w. 1905.
57. Cf. J. Clay and T. Clay, Jolles, Proceed. Kon. Akad. Wet. Amst., *35* (1932), p. 69-82, and 172-185, and: M. P. Vrij., Dissert, Amst. (June, 1932), (especially pp. 60-61).

In daylight, especially in direct sunshine, numerous dyes become bleached while in the dark they remain unchanged for a long time. Numerous organic materials, in the pure, colorless state when exposed to light and air, are in the course of time discolored and become gummy.[58] Whether it is always the direct action of the light rays which is responsible for this, is a question. It is also possible that the rays produce ozone or hydrogen peroxide, to which must be ascribed the action and decomposition. Perhaps we may have to fall back upon the dehydration theory of Wieland[59] for explanation; according to this theory activated hydrogen and not oxygen is the first agent. "It is characteristic in the processes referred to here, that always oxidation and reduction accompany each other, even though that reduction is in many cases a reduction of free oxygen to water." In the case of the alteration of plant remains which we have already broadly considered, the oxidation must ultimately lead to carbon dioxide and water. Thus we can visualize the enzymes such as oxidases, peroxidases, catalysts, etc. in the plant residues, acting as do the inorganic catalysts such as Fe, Mn, Cu, etc.

Therefore there is no sense in further discussing this subject which has not yet been entirely worked out experimentally as to its application to the soil. Suffice it to mention that if sufficient breaking down and oxidation of plant remains in a non-biological manner exists to an appreciable degree in the tropics, then because of the high temperature, the abundant light, and the high content of iron oxide in the colloidal condition in many kinds of soils, this oxidation will certainly be of more significance than in the regions of the earth which are cooler and have less light.

* * * * *

This, however, does not deny that everywhere in the world the changes which the plant residues undergo as a result of the action of the fauna and the microflora on and in the soil remain of very much greater significance.

The progress of soil science in this field in the last ten years has been bewilderingly great. It can be said without exaggeration that almost every month important new discoveries have been added. But all that is new does not come from the Netherlands Indies; in 1932 not even a single soil microbiologist was working there.[60] In Europe and the United States of America they are found by tens. So in this respect in comparison with higher latitudes the tropics are seriously backward. It is to be hoped that there will soon be an improvement.

Hence what is to be discussed here is science in general and, for a preponderant part, science of the temperate climatic zones. In doing this we must be continually mindful of the necessary adaptations to be made, while even the principles must be applied with caution to the soils of the tropics.

As has already been said on page 97, we first of all differentiate the "organic matter" into dead plant remains and living organisms. The most important constituents of the discarded and dead parts of plants are:

a. Substances easily soluble in water as salts (for example the ions NH_3, K, Na, Ca, Mg, SO_4, Cl, NO_3), and in addition sugars, starch, amino acids, etc.
b. Soluble but "difficultly decomposable" tannin substances and the like.
c. Substances quite insoluble in water, but "easily decomposable," such as cellulose, pentosans, etc.
d. Insoluble and difficultly attacked substances such as lignin, cutin, resins and waxes.
e. The nitrogen-containing "protein substance."

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58. Cf. Commentaar op de Ned. Pharmacopae., 1, p. 21.
59. Cf. G. Van Iterson, Jr., Rectorale rede, Delft, (8 Jan. 1926), p. 13-15.
60. The five that since 1905 have been active in this field in the Netherlands Indies, have all left and have not been replaced (1932).

Now each of the groups of soil organisms mentioned above (page 97) attacks these different sorts of organic substances (a-c) in its own peculiar way, and even within each group the many different sorts of organisms again have their own preferences and methods.

It is obvious that in a book such as this we cannot go into all these interesting particularities[61] which arise; it is imperative that we restrict our discussion to important general points.

* * * * *

Quantitatively, bacteria and molds certainly do the most work. Which of the two is the most important depends more or less upon the magnitudes of the following factors: moisture, access of air, temperature, degree of acidity, supply of food materials.

The "resting spores" of almost all the microörganisms in question can endure a relatively intensive and sometimes long-continued drying out; other spores and the vegetative forms, however, cannot. They grow only in the presence of much moisture; bacteria proper only with such a degree of moisture that the relative humidity of the air around them is at least 98 per cent. Molds can thrive with less moisture, that is, with a relative humidity as low as 85 per cent. In a medium wherein the relative humidity varies between 85 and 98 per cent, the molds are practically the only microörganisms that grow.

The supply of air is important only in so far that this determines the supply of oxygen, both in gas form as well as dissolved in water. With an abundant supply of oxygen, molds grow very much better than with a deficiency. Of the bacteria, this also applies to the aerobic sorts; with a shortage of oxygen or an entire absence of it anaerobic bacteria come into the foregound although some kinds can adapt themselves to both conditions.

As to the temperature, three broad groups, each with its own minimum, optimum, and maximum, can be differentiated. They are the psychrophilic microörganisms with an optimum around about 10°C the mesophilic which have the optimum about 25 to 35°, and the thermophilic with the optimum about 50 to 65°. In no sense however are these sharp boundaries. Most forms belong to the mesophilic group; at least, this is the case in temperate regions. In the tropics one might expect that <u>if</u> a shifting takes place (which may be of no significance), it would be toward the thermophilic side. In a general way this applies to the bacteria, with which we include the actinomycetes. The molds have a temperature optimum which somewhat resembles that of the higher plants, whose optimum lies somewhat lower, around 18 to 25°C. From this it should follow that below 25° or 20° the conditions become more favorable for the molds as compared with the bacteria. However, if the temperature rises above 30°, and especially if above 35°, then the conditions of life for the molds become much less favorable, while at this point certain bacteria flourish luxuriantly.

The degree of acidity of the medium is an influence not to be underestimated. With a pH of 6.5 to 7, or somewhat more generally from 5.5 to 7.5, the bacteria are in their element. The actinomycetes prefer a pH greater than 7, and in an acid medium they decrease in number. In more acid surroundings, with for example a pH of 5.5 to 3.5, the molds obtain the upper hand, since this degree of acidity suits some kinds. Other kinds do not so much prefer this degree of acidity, but they are better able to resist strong acidity than the bacteria, which in such a sour medium with an increasing degree of acidity greatly decrease in number. Hence, in soils just about neutral, bacterial activity predominates, while in acid soils, the molds sound the dominant note.

When we come to the food materials of the microörganisms, a differentiation must be made between the true organic

61. Cf. the extensive treatment of this research in: Handbuch der Bodenlehre VII, p. 113-104 (<u>sic</u>) under the title K. Maiwald, Organische Bestandt. d. Bodens. Further the excellent work of E. John Russell, Soil cond. and plant growth, Chaps. V-VII. A. Dan Rippel, Handbuch der Bodenlehre VII, p. 245-248: Alg. Bemerk. Ü.d. Lebensbed. d. Mikroorg. im Boden. Finally S. Waksman, Principles of soil microbiology (1927).

constituents and the inorganic with which not only Ca, K, Mg, etc., and P_2O_5, SO_3, Cl, are included but also NH_3, NO_3, NO_2 and CO_2. The latter group is more important to the molds, while the former is of greater weight for the bacteria.[62] This presumably is connected with the following characteristics of these two types of soil organisms. With respect to the role which is played by the molds in the conversions in the soil, Russell[63] says: "that they are, of all soil organisms, the most economical in their metabolic processes, transforming into their own body substance more of the carbon of the compounds they attack, and dissipating less of it as CO_2, than any other group of organisms in the soil;....they may transform into fungal tissue as much as 50 or 60% of the compound decomposed." --In contrast with this we read on page 402; "An interesting distinction has been observed, however, between bacteria and fungi. Fungi reassimilate 20 to 60% (usually 30 to 40%) of the carbon of the substratum they have decomposed, while bacteria reassimilate much less, only 1 to 30%, usually 5 to 10%. But for one part of carbon assimilated, bacteria assimilate considerably more nitrogen than do fungi, containing in their dry substances 10-12% N against 5-8% in the dry matter of fungi."

The bacteria are thus indicated as the organisms which really break down the organic matter remaining over from the plants; the molds convert the materials, at least in part, into new organic matter which remains behind in the soil. Rippel[64] also expresses this notion more strongly than does Russell: "Fundamentally in quantitative relations bacteria and molds may be differentiated (if one excepts the resins) in this respect: the molds, as *Aspergillus niger*, use about 1/3 of these prepared organic materials for the building up of the body substance of the organisms, the bacteria use only about 1%. Thus in mineralizing, bacteria will work more rapidly while molds fix organic substance stronger and longer."

If we now ask: for the tropics, what significance is to be attached to the results stated above?--then, as a point of departure we may say that, taking into consideration that the average soil temperature is much higher than in the temperate regions, therefore the bacterial activity predominates over the molds. The higher the temperature rises above 30°, for example, the clearer this advantage becomes. On this account in the lowlands in the tropics, bare soil which is adequately moistened by the rain will exhibit a flora predominatingly bacterial; while a heavily wooded terrain in the mountains at such an elevation that the soil temperature becomes about 20°C will have a flora in which molds predominate. These various things being true, it would seem that these generalizations which are the results of experiments being carried out in Europe, might be applied directly to conditions in the tropics. And this is confirmed by the following statement by Russell:[65] "So far as is known, the composition of the soil population shows remarkably little variation in different parts of the world. The characteristic groups of algae, bacteria, fungi and protozoa are the same in the Arctic as in temperate and tropical climates....."

Now where the bacteria have the upper hand, that is with a high temperature, much moisture and with but limited supplies of air, the optimal conditions are found for the mineralization of plant residues, and this combination of conditions is particularly well developed in the moist, low, hilly lands of the tropics. The consequence is that but little organic matter can remain either in the original or transformed ("humus") state. But above about 1,000 m. elevation the temperature is much lower, the molds, which have a less drastic effect upon the organic matter, even though it be conserved in their own bodies, obtain the upper hand. Thus even with much moisture and good aeration, the higher the elevation, the more humus that remains. But since the destruction is roughly proportional to the vegetation,

62. H. L. Jensen, Various papers published in 1931 in: Soil Science and Journ. Agri. Science, as well as Rothamsted Mem., Nos. 14 and 15.

63. E. John Russell, Soil conditions and plant growth, 6th Ed., pp. 387 and 402.

64. A. Rippel, Handbuch der Bodenlehre, VIII, p. 602.

65. E. J. Russell, l. c., p. 418.

this humus content cannot continue to increase indefinitely. With 2 or 3 times as much humus the mineralization is thus 2 or 3 times as great. Although the vegetation may increase the organic matter somewhat, it cannot increase it greatly.

When in the tropics a terrain stands under water, this means that free oxygen is lacking so that the conditions are unfavorable for most of the molds. Of the bacteria only those kinds can grow which are anaerobic or facultative anaerobic. They will continue to grow as long as the soil and/or the water (as well as the vegetable remains) offer adequate quantities of inorganic food materials. In the low coast land of the Netherlands Indies swamps and marshes are found which answer to this description. The result is that while there is an important amount of mineralization, this process is less active than on land which is not submerged. Consequently there is a small to moderate formation of humus, the smaller, the higher the pH. Such conditions are, for example, found in limestone tracts. This is the simple reason why peat is never found in limestone tracts in the Netherlands Indies where, because of a considerable content of lime in the form of bicarbonate, the water is "hard." This is also why the water in peat is never hard. Fresh volcanic ash also gives alkaline water, rich in Ca and Na. Thus the ash also has a favorable action upon the bacterial life, so that as long as the pH remains between 7 or 8 and 6 or 4.5, the chances of peat accumulation are small or negative. If however the ash is so far weathered out that practically all the Ca and Na have disappeared, then the possibility of humus accumulation exists. But the pH has most probably fallen to 4 or even lower, the medium becoming very acid.

There is also the chance of an acid medium where, from the beginning, the Ca and Na are either lacking or reach but very small concentrations. This might occur in the region of the "acid" (silicic acid-rich) rocks such as granite, liparite, and sandstone. In conformity with these conditions there is found on Java but little peat, while on the contrary, there is much of it on Sumatra, Banka and Billiton, Borneo, and New Guinea.

* * * * *

If on the basis of the preceding presentation we now endeavor to draw a graphic picture of what, for example happens to the waste material from a tree in the tropical high forest, we would arrive at something like the following:

Leaves, twigs, flowers, and fruits fall, and now and then heavy branches. Once on the ground they are immediately attacked, bored through by all sorts of gnawing insects, in a word they are principally broken up mechanically. In the meantime (sometimes even before they had fallen) the mold spores attach themselves to the fallen parts of the plants and the molds disintegrate the solid connections more and more. At least in loose soil, ants, termites, worms and other animals take a great deal of the pulverized mass down into the deeper layers of the soil. But if the soil is very hard, then usually that depth is not more than a few cm. However various changes of a chemical nature have also already occurred: out of the plant remains the easily soluble constituents have been partly dissolved in the rainwater, and have thereupon gone with the water directly into the ground. Another portion of the dissolved material has been carried away for good in the runoff water. With the mixing of cell contents after the death of these cells there have occurred all kinds of reactions. For example tannin will precipitate with protein-like materials to form products which in a certain sense one can think of as leather. --But, if that complex of materials, summed up above under (a) to (e) (see page 105)has once gotten into the soil, then the great breaking-down begins.

All groups of soil organisms immediately start fighting over the easily dissolved materials. Sugar and starch are completely mineralized by bacteria to CO_2 and water. From these substances, molds sometimes leave quite a little dark colored residue (i.e. "humus"). The fate of the cellulose depends upon the reaction in the soil; in neutral or weakly acid soils it is the bacteria, the "cellulose devourers," which in a relatively short time (a few weeks) can thoroughly clean out the soil and transform the cellulose into CO_2 or, in the presence of less oxygen, into organic acids. In an acid medium (pH = 4 or

lower) molds use the cellulose in their transformations of matter. Some molds produce, beside their own tissue, "humus." Whatever the organisms which attack the cellulose, in every case they need nitrogen, and the degree of attack is proportional to the quantity of N. About this N we will have more to say (see pages 110-111).

Because of the N compounds in them, with which the organisms build up their own protein, the proteins of the waste materials are also very much desired by the soil organisms. If the protein of the plant remains has been used up, then the microörganisms eagerly use each other's "corpses," if one may thus speak of the dead bacteria and mold cells.

Apart from their fixation on proteins, the tannins react chemically, for as soon as they come in contact with free oxygen, especially in the presence of enzymes acting catalytically, they readily oxidize to dark colored, complex aromatic compounds, called phlobaphenes. While the tannins are in less demand as food, yet in the absence of better materials they do not remain unattacked. Something the same can be said of the lignins; but how the materials are transformed is not yet known. In each case the change occurs slowly and owing to this their products of partial conversion also form a part of the "humus."

Resins, etherial oils, fats, and waxes are also ordinarily long resistant. For most soil organisms, they seem to be unattackable or at least broken down only with difficulty. In the long run, however, there seem to be some organisms which have a use for even these resistant substances.

Now what are the organic substances which may at any one time be found on and in the soils of the tropical high forest? --They are, 1st, original unattacked plant remains (as divided above under (a) to (e); also 2nd, living molds in the form of a mass of mycellial threads running through everything-- living bacteria; dead mold cells and bactéria; and finally 3rd, undecomposed, but also in part undigestible remains of plants, waste products of the molds, and waste products of the bacteria.

* * * * *

Formerly all the materials summed up under (1), (2), and (3), were lumped together and called "humus." Preferably, this is no longer done. Provided that from group (3) are separated CO_2, NH_3, NO_2, NO_3 and inorganic salts, all the rest may quite well be called "organic matter."

Meanwhile what is meant by "humus" has become somewhat uncertain, and we find almost as many definitions for it as there are investigators who are interested in it. Grandeau called "matière noire" that part of organic matter which could be extracted with lye or ammonia. This is a practical approach but if this "humus" is compared with the above division into three groups, then it comprises: a small part of (1), a small part of (2) and a quite large part of (3). Obviously this does not tell us much.

Besides the total C content, from which may be calculated a somwhat problematical total organic matter content, others determine the organic matter which can be oxidized by $KMnO_4$ or by H_2O_2. But what one really determines, and what not, is however still vague. To connect with these the conception "humus" is at least just as vague. It would seem perhaps best to eliminate the conception and word "humus" and for the time being give preference to conceptions which can be practically defined, and to endeavor to get a deeper and deeper insight into these organic substances in the hope that in due time "humus" can also be spoken of as an entity that is unambiguous and has sense.

* * * * *

Meanwhile, in order to get an adequate conception of what occurs in the living soil, it is unavoidable to devote a few pages to nitrogen and its combinations. Simply taking cognizance of a number of chemical facts doesn't get one very far; the biological interpretation must go along with them.

Nitrogen is taken up by higher plants in simple inorganic forms. Many plants prefer nitrate nitrogen but there are also plants which definitely prefer to take up N as ammonia. It is probable that some plants can also take in N in the form

of asparagine and similar sorts of easily soluble amino-amids, which then serve as bonds in the building up of protein.

Now, whenever parts of plants are broken down the cells die and then there are liberated: nitrate not yet worked up, protein, amino-amids as splitting off products of protein, and therefrom again ammonia, if any. In these four forms the plant-N returns to the soil again. In attacking those four forms the soil organisms in a certain sense seriously compete with the plant roots. Apparently the microörganisms directly take up NO_3, NH_3 and amino-amids. They first break down the protein and bring it into a form that can be taken up. From the combined N absorbed they form their own protein.

As has already been said above, at the same time these same organisms break down non-nitrogenous constituents of the plants, such as cellulose, and feed upon the products of the decomposition. Thus they build up their C and N containing bodies.

By chemical analyses, total C and total N in the soil are quite easy to determine. Consequently such figures are available in great numbers. It has been established empirically that the C/N ratio is approximately as indicated by the following figures (Table 45):[66]

It is notable indeed, that in so many and such different kinds of soil the ratio C/N varies only from 10 to 12. Besides, it has been observed that where a marked divergence does exist, there is a striving toward a sort of equilibrium, wherein C/N will be about 10 to 12. Also under normal conditions of adequate moisture and adequate air such an equilibrium can always be reached.

If, for example, C/N is much too high, then this signifies a surplus of constituents of the group A, of the C-rich food materials for the microörganisms. Then they attack it, are economical with the N, and produce much CO_2. Meanwhile they multiply strongly. By so doing the C 'content falls in the desirable direction. If there be too little N present, then through fixing of N from the air, the N-fixing bacteria make up the deficiency in order to build up their own bodies. This also works in the direction of lowering the C/N.

If man adds N fertilizers in the form of NH_3 salts or nitrate to the soil under the conditions mentioned, then the microflora is thankful for it and considers it an inducement to suspend temporarily the laborious fixing of atmospheric N, and to make itself master, to its own advantage, of the easily taken up N food materials.

Table 45

C/N RATIO IN VARIOUS ORGANIC MATERIALS

Group	Material	Content in % C	Content in % N	Ratio C/N
A	N-poor cereal straw	45	0.5 or less	90-100
A	Leaves of non-leguminous trees			50
A	Hay of some legumes			30
A	Entire plants with flowers and seeds	45-50	1.5-3.5	15-30
A	Residues of nitrogen-rich plant parts	50	2-3.5	11-25
	Good farm yard manure (A + M)	56	2.5-3.5	15-20
B	"Organic matter" in the soil (without unattacked parts of plants)	58	5-6	10-12
M	Fungus mycelium	45	4-8	6-11
M	Bacteria	40-50	10-12	4

66. Russell, l. c., pp. 312 and 402. Maiwald, Handbuch der Bodenlehre VII, p. 183 where is also other literature.

So it may happen that cultivated plants on a C rich soil may be entirely unable, at least in the beginning, to profit by a N fertilization. If the microflora robs them of their inorganic food materials as well, the crops may even decline. The soil strives toward a good C/N ratio but under these circumstances the ratio may even fall much lower.

If however the C/N is lower than 10 this indicates a relative deficiency of undecomposed plant remains, or the presence of too many microörganisms. These may secrete N in inorganic form. But if the reaction be weakly alkaline, neutral, or at most weakly acid, and if there be adequate air, then the nitrifying bacteria are in their element and produce nitrates. If the reaction be more acid, then molds come more into the foregound, and they secrete NH_3. In both cases the N content of the "organic matter" decreases and the ratio C/N approaches 10. --Where aeration is inadequate but water abundant, ammonia may also be secreted by bacteria while CO_2 is simultaneously produced; thus oxidation and reduction go hand in hand.

This presentation is very simple indeed. In real life there is much else that happens which has not been mentioned here. The vital processes already touched upon also continue in the soil to a great extent parallel with each other, sometimes a little more one way, sometimes a little more the other. Now elemental N is fixed by the soil, then again liberated as NO_3, NH_3 or even as elemental N. But this does not particularly affect the relatively simple final results. Besides this there are C compounds taken up, even CO_2, (by algae); and usually CO_2 is secreted. Sometimes however (in case of deficiency of air, such as in swamps) it is given off as marsh gas (CH_4).

Thus in accordance with the conditions, the microflora in the soil appears to be quite subject to radical alterations. In its biological composition, important shiftings can occur, sometimes even in a short time, while quantitatively certain groups sometimes increase enormously. Then again they suddenly almost entirely disappear. Among the factors which seriously inhibit the activity of the microflora the following may be mentioned:

1. Depression of the temperature makes the microflora less active in breaking down, or mineralizing the organic matter In the tropics, the higher one goes in the mountains with conditions otherwise similar, the slower the mineralization, and the more "humus" accumulates in the soil.

2. The more acid the medium, for example below pH 4.5, the more bacterial activity is eliminated. A reaction of that degree of acidity obviously is related to a lack of mineral plant food materials such as Ca, K, and Mg. Consequently all life in the soil will be restricted. And so there remains over more organic material, and peat formation occurs.

3. If there be a lack of oxygen, for example, due to the soil remaining continuously under water, then only anaerobic organisms can thrive. They can only live upon the organic matter available to them, by coupling the development of CO_2 (oxidation) with an extensive reduction ("eikohlung", a partial carbonization), when there are available adequate nutrients, as from fine volcanic ash. In this is possibly the explanation of the formation of certain intensive black kinds of soils. If however in a medium with an acid reaction there are lacking the inorganic nutrients, then the organic matter remains as it is and an accumulation of peat results. But now without that "carbonization," at least in the commencement,[67] peat deposits in the tropics, especially very recent ones, are more apt to be brown, at most dark brown rather than black.

* * * * *

4. THE PRINCIPAL WAYS OF WEATHERING

After a discussion of the formation and the breaking down, or mineralization, of organic matter on and in the soil, it is now possible to consider the influence of these changes upon the composition of the weathering liquids, so that we will then

67. During a very long time, in geologic times, carbonization has occurred also without the biological help mentioned and peat has become lignite and coal.

be able to give the different main ways of weathering.

Here we will do this schematically. Opinions may differ as to whether the time has already come to propose such a scheme as is developed and set out in the following pages, for it is a question whether adequate data are yet available to substantiate the details of this scheme, and whether in the course of time it will not perhaps have to be radically altered. It seems to me that as soon as objective observations have yielded a quantity of data along inductive lines, deductions should be made as rapidly as possible. Such deductions, which in no sense should be confused with superficial or unanswerable speculations, will serve as working hypotheses for further progress in soil science. In conformity with this conviction, years ago[68] I aspired to unite into a schematic outline the various facts and the probably occurring possibilities. Later these were[69] somewhat modified. And again, after another and very valued stay in the Netherlands Indies (1930-1931), the earlier scheme has been again amplified[70] in order that in this book it might be presented in its "provisionally" final form. By "provisional" I wish to express the idea that as a result of many new observations, analyses, and other researches, new insight and ideas will, without doubt lead to all kinds of improvements and amplifications in the scheme.

* * * * *

Main lines of differentiation

The main features by which the different forms of tropical weathering can be distinguished from each other are:

1. the temperature
2. the water movement in the soil, and
3. the access or exclusion of air (oxygen).

In addition to these we must also define the state of affairs at the moment, that is:

4. the stage at which the weathering process has arrived.

It may be noted that the "organic matter" is not mentioned here. The reason for this is that the organic matter is not a primary factor, but a secondary one, which is dependent upon the four factors which have already been mentioned. It is true that in nature there is nothing which is absolutely independent from other things, but the vegetation is yet so dependent upon the four main lines which have been mentioned that, apart from the nature and the form of the parent material, they very largely determine the weathering form. Only the activities of man bring about such radical modifications of the situation as to necessitate separate consideration. These will be taken up after the treatment of the natural processes.

In the same way the degree of acidity of the weathering medium is not considered a primary weathering factor; the degree of acidity which one may choose is entirely to be deduced from the stated factors.

* * * * *

1. As long as one has his eye only on inorganic chemical processes within the temperature ranges possible in the soil, there are no essential differences with

68. E. C. J. Mohr, Over den Grond van Java. (Batavia, 1911).
69. E. C. J. Mohr, Tropical soil forming processes with special reference to Java and Sumatra (Translated by Robert L. Pendleton), National Geol. Survey of China Peiping (1933).
70. V. J. Koningsberger, E. C. J. Mohr, G. A. Neeb, De genetische Classificatie en Kaarteering der Java-Suiker-gronden, Meded. Pr. J. S. I. (1931), No. 16, Archief 1931, III, p. 625. (Under the title "The Genetic Classification and Mapping of Java Sugar Cane Soils" this paper has been translated by Robert L. Pendleton. A typewritten copy of this translation as Bureau Pamphlet No. 2320 is available on loan from the Imperial Bureau of Soil Science, Harpenden, England. See also Monthly Letter No. 39, Imperial Bureau of Soil Science, for January, 1935.)

different temperatures. It is true that with higher temperatures chemical processes go on somewhat more rapidly, but the curve is smooth. In other words, we can just as well use 3 intervals of 10°C, as 5 intervals of 6° to differentiate between places with an average temperature of 0° and 30°C. Either units have just as much or just as little sense. But once we direct our attention toward the vegetation, which is correlated with the temperature on and in the soil, then it becomes different.

Then as has been shown above (see page 107)[71]--there is a limit, at least with adequate aeration, above which the mineralization of the plant remains takes place just as rapidly or more rapidly than the production of organic matter by the vegetation. Once equilibrium has been reached, there is no accumulation of organic matter, but rather at any particular depth there is a constant amount of organic matter in the soil. With increasing depth there is a decreasing amount of organic matter, for it disappears as fast as it accumulates.

Depending upon the nature of the vegetation and the soil conditions this critical temperature varies between about 24-30°C, or on the average about 25-27°C. Then, for the Netherlands Indies, this temperature indicates the boundary (about 200 m. elevation) between the tropical lowlands and the lower mountains or hilly country.

A second boundary, also vaguely defined, with an average temperature which does not rise above 20°C, is found at about 1,000 m. elevation. Between the 1st and 2nd boundaries palms are still to be found, but not above the 2nd one. Higher than this in the tropical mountains, even frosts occur, especially on flat places and in depressions.

In the tropical hill lands (200-1,000 m.), with the increase of the forest vegetation, the content of organic matter gradually increases with the elevation. On the other hand without that vegetation the organic matter decreases, usually rapidly, both through mineralization and through erosion (more about this later on).

A third boundary can be drawn at somewhere around 1,800 to 2,000 m. elevation, thus with an average temperature of

$$25^\circ - \frac{1,800 \text{ to } 2,000}{160} = \text{about } 12^\circ \text{ to } 14^\circ\text{C}.$$

Above this boundary the tropical high mountains occur, which in the Netherlands Indies are, for the most part, limited to the tops of mountains, and only in New Guinea do they embrace extensive areas of high land. As one goes higher, the vegetation becomes less and less luxuriant. Above 3,000 m. where the temperature averages 5°-8°C, the forests shrink to elfin-wood. Above 4,000 m. the tree vegetation ceases, while at about 4,400 m. lies the snow line, and on exposed points and ridges it lies even lower.[72]

In short--with the three boundaries mentioned, the Netherlands Indies can be divided into four zones (hot--warm--temperate--cold):

Zone or Belt[73a]	Average temperature	Elevation
(He) The tropical lowland	27°-25°C	0- 200 m.
(Wa) The tropical foothills or lower mountains	24 -19°C	200-1,000 m.
(Ma) The tropical mountains	18 -13°C	1,000-1,800 m.
(Ko) The tropical high mountains	12°--above the snow line	1,800-4,800 m.

In Central America (Guatemala) similar boundaries have been established[73]; there the zones have the following names: From sea level to 600 m. "tierra caliente" = the hot land; that from 600 to 1,800 m. "tierra templada" = the temperate land; and above 1,800 m. to more than 4,000 m. "tierra fria" = the cold land. Here, just as in the Netherlands Indies, each zone has, besides the most suitable cultivated

71. Compare also: E. C. J. Mohr, Handel. Nat. en Geneesk. Congres 1913, p. 483-491.

72. Compare for New Guinea: A. A. Pulle, Botanisch Verslag in Bull. 68 der Mij. t. bev. Natuurk. Ond. Ned. Kol., p. 33-37; and especially: H. J. Lam, Bot. Result. Noord-New Guinea Exp. 1920, Teysmannia, 32, (1921), p. 289-326.

73. W. Köppen, Die Klimate der Erde. References in Handbuch der Bodenlehre, II, p. 37.

73a. Dr. Wilson Popenoe writes (personal communication): As recently pointed out by the erudite Pittier (Pisos Altitudinales in Apuntaciones sobre la Geobotanica de Venezuela, Caracas. Lit. y Tip. del Comercio. 1936) it is a mistake to refer to these as zones. He recommends "belt"...Zones are definitely latitudinal concepts from which the climates of tropical regions differ because (1) they have much narrower ranges of temperature, both diurnal and annual, and (2) they have narrower ranges in

crops, its own natural flora. In the Netherlands Indies, however, except for a little tea and cinchona, it is no use to search for cultivated plants above 1,800 m. (6,000 ft.).

For Java, Junghuhn,[74] in the middle of the last century, was the first to give an estimate of the area or extent of the different elevation belts. His classification however was on the basis of plant distribution and not on topography. He supposed:

the first vegetation belt of				0-2,000 ft. = 0-487.5 m.[75] about 98% of the area.
" 2nd	"	"	"	2000-4500 ft. = 487.5-1462.5 m. not even 2% of the area.
" 3rd	"	"	"	4800-7500 ft. = 1462.5-2437.5 m. at most 0.02% of the area.
" 4th	"	"	"	7500-11,000 ft. = 2437.5-3575 m. an insignificantly small and unimportant part of the area of Java.

Since Junghuhn's time the topographic map material has been very greatly added to, so that now (1933), at least for Java, it is possible to measure off the areas on the map, although measurement is not yet possible for the remaining great islands. The results for Java, obtained by measuring with a polar planimeter on the topographic map,[76] will be found below in Table 46.

In this table in comparison with the above recorded scheme we find a couple of divergencies. The zone of 200-1,000 m. divided into two zones, one of 200-600 m. and another of 600-1,000 m. Further the contour of 1,800 m. is not on the topographic map which served as the base, hence the boundary has been moved to 2,000 m.; so that the measuring could be carried out.

This measured result varies markedly from Junghuhn's estimate. Contrasted with less than 2% of the area above 487.5 m. the measuring showed 18% above 600 m. More than 2/3rds of the residency of Central Priangan is above 600 m. But Junghuhn did not have at his disposal maps such as we have now.

* * * * *

2. With reference to the water movement in the soil we now return to the view taken on pages 62 and 67; which is this, that very pervious soil material is differentiated from slightly permeable or impermeable. We shall begin by considering very pervious material, and for the first case, that in which the water movement is:

a. continuously in a downward direction. This is the case in those regions, which in the description of the climate (page 58ff.) were classified as tracts with a continuously wet climate. Even though there is detectable a dry season (an east monsoon) yet it never becomes "dry"; at most there is less rain than in the west monsoon, but the rainfall of every month is more than 60 - 100 mm. Continuously fresh rainwater is added to the soil liquid. The weathering is a continuously leaching out weathering, from above downwards, always penetrating deeper and deeper. As the uppermost layer leaches out, all kinds of constituents are yielded to the water so that as it goes deeper it cannot take up more. Later however, if the water no longer becomes fully saturated in the surface layers it dissolves more constituents in the deeper layers and leaches them out.

b. If after a wet west monsoon a clearly dry east monsoon prevails--(the reverse also occurs; therefore it were perhaps better to speak of a periodical alternation of a wet and a dry season),--

74. F. Junghuhn, Java, 2e duitsche uitg. (Leipzig, 1857), Dl. I.

75. 1 foot considered as 0.325 m., l. c., p. 48.

76. Painstakingly carried out by Mr. J. van Male, for whom is here a word of recognition and thanks.

Table 46

EXTENT OF THE ELEVATION ZONES OF JAVA AND MADOERA IN SQUARE KILOMETERS
AND PERCENTAGE OF THE AREA (ROUND NUMBERS)

District	He lower than 200 m.		Wa$_1$ 200-600 m.		Wa$_2$ 600-1000 m.		Ma 1000-2000 m.		Ko Higher than 2000 m.		Total
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2
Bantam............	5720	72	1610	21	450	5	130	2	---	---	7900
Batavia...........	2900	100	---	---	---	---	---	---	---	---	2900
Buitenzorg........	1910	51	1110	29	430	12	280	8	7	0.2	3750
West-Priangan.....	1610	20	3410	43	1830	24	940	12	36	0.5	7850
Midden-Priangan...	400	8	1220	25	1580	33	1580	33	64	1.3	4850
Oost-Priangan.....	1420	16	4550	52	1600	18	1130	13	61	0.7	8750
Krawang...........	3820	76	770	16	230	5	130	3	3	0.1	4950
Indramajoe........	2730	81	290	9	220	7	100	3	14	0.4	3350
Cheribon..........	1310	58	660	29	200	9	65	3	11	0.5	2250
Pekalongan........	3440	61	1230	22	540	9	410	7	40	0.7	5650
Banjoemas.........	3470	62	1180	21	450	8	420	8	35	0.6	5550
Kedoe.............	960	18	2900	53	940	17	590	11	78	1.4	5450
Jogjakarta........	1780	57	1280	41	74	2	10	0.3	2	0.1	3150
Soerakarta........	3150	52	2160	36	460	7	230	4	34	0.6	6050
Semarang..........	6080	74	1490	18	440	6	180	2	10	0.1	8200
Rembang...........	6580	88	870	12	---	---	---	---	---	---	7450
Madioen...........	3050	52	1890	32	660	11	250	4	36	0.6	5900
Kediri............	4040	57	2280	32	590	8	190	3	19	0.3	7100
Soerabaja.........	5370	91	270	5	110	2	130	2	13	0.2	5900
Pasoeroean........	2180	25	3870	44	1270	14	1170	13	353	4.0	8850
Besoeki...........	4660	47	3320	33	1000	10	930	7	147	1.5	10050
Madoera...........	5270	96	210	4	---	---	---	---	---	---	5500
Total.............	71900	54	36550	28	13050	10	8900	7	950	0.7	131350
			82		38		17				

then, if the thickness of the easily permeable horizons of the soil, counting from the surface to the ground water level, is greater than the height of the capillary rise in that series of layers, the ground water never can rise up to the surface. If the difference in question is more than 1 m., then the ground water as such can never arrive in the drying out zone during the dry monsoon. Thus the upper layers dry out. The little rain that falls as showers remains suspended in the upper layers and rapidly evaporates again. In short, the water movement stands practically still, only in the following wet season does the leaching out process commence again. Hence there is not a continuous but an intermittently leaching out weathering.

c. If there are similar climatic conditions as under (b), but if the ground water stands so high that through ascending in the dry season it can come up into the zone of evaporation, by which then again fresh liquid from beneath follows after, then there is in the rainy season a downward movement of water in the soil and in the dry season an ascending movement. Consequently a periodically

alternating water movement occurs. Hence there is an alternation of dilution or leaching and concentration, and so an alternating weathering.

Although leaching out and concentration can be in equilibrium with each other, this of course occurs just as seldom as in a business enterprise income and expenses precisely equal each other. If the leaching out predominates, then in the course of a long time the result inclines toward that of (b) or (a); if the ascent and concentration predominate, then the result tends toward the following case (d).

(d) and (e). The case where the water movement in the soil is exclusively in an upward direction, so that there can only be an ascending water movement, either intermittent (d), or continuous (e). This situation does not occur in the Netherlands Indies.

Apart from Paloe, the station on Celebes which occupies such an exceptional place in the rainfall statistics that Boerema[77] devoted a separate publication to it, no place in the Netherlands Indies can be pointed out where there are not two or more months of the year during which fall at least 100 mm. of rain. Thus everywhere there are at least a couple of wet months. From all the 3,300 stations[78] the following 20 are the only ones with monthly averages which never go above 200 mm. At all other stations there is at least 1 month per year with more rainfall than 200 mm. (see Table 47).

Since various of these stations have been established only a short time

Table 47

RAINFALL STATIONS IN THE NETHERLANDS EAST INDIES WHICH HAVE MONTHLY AVERAGES LESS THAN 200 mm.

Station	Highest Monthly Average	Number of Months Averaging above 100 mm.	Number of Months Averaging 100-60 mm.	Number of Months Averaging under 60 mm.	Average Total Annual Rainfall
Ilwaki (Wettar).....................	161	2	4	6	715
Lombok (Lombok).....................	154	3	3	6	758
Bora (Celebes)......................	119	3	5	4	939
Tandjongloewar (Lombok).............	198	4	0	8	873
Waingapoe (Soemba)..................	177	4	1	7	791
Melolo (Soemba).....................	156	4	1	7	831
Selong (Lombok).....................	194	4	1	7	929
Asembagoes (East Java)..............	196	4	1	7	909
Waiwerang (Solor)...................	188	4	2	6	836
Laboean Badjo (Flores)..............	188	4	2	6	928
Soember Waroe (East Java)...........	196	4	2	6	947
Maoemere (Flores)...................	175	4	2	6	977
Loewoek (East Celebes)..............	130	4	5	3	969
Amboenten (Madoera).................	185	5	2	5	1008
Endeh (Flores)......................	174	5	3	4	1146
Batangmata (Saleier)................	138	6	3	3	989
Wonreli (Kissar)....................	174	6	1	5	1018
Padang Gelai (Palembang)............	151	7	1	4	1185
Singkarah (Sumatra's West Coast)....	176	8	4	0	1440
Panggoeroeran (Batak lands).........	176	9	2	1	1532

77. J. Boerema, Over het klimaat der Paloe-valei., Nat. T. schr. v. Ned. Ind., 77 (1918), p. 47.
78. J. Boerema, Kon. Magn. Meteor. Observ. Verhand. No. 24.

it is quite possible that in the course of time even some of these may yet drop out of this list. This leads to the following conclusions: 1st--Places where the whole year through is "dry," (that is, the monthly rainfall always remains less than 60 mm.) certainly do not occur in the Netherlands Indies; 2nd--places where more than 4 months of the year have a rainfall of more than 100 mm., making possible a deep penetration of the water into the soil, belong to the three exceptions which may for the present be neglected--since these cases are yet to be fully confirmed.

The driest case which one can imagine for the Netherlands Indies is where a soil, which as a result of a large water capacity, even with 2 to 4 wet months, takes up and holds fast all the rain water, which thereafter again disappears in the dry season through evaporation, so that the sub-soil has no chance at all of becoming moist. It is very much of a question, whether in the Netherlands Indies such a case actually occurs, except at Paloe, as mentioned.

If in a case of that sort the subsoil would still be supplied with water which comes in from elsewhere--for example by an underground stream down along a mountain slope on the upper part of which it does rain abundantly,--then there would still be a possibility in the Netherlands Indies for cases (e)--or (d)--, that is, a continuous or intermittent upward movement of the water in the soil, a phenomenon which one certainly feels is not at all common but a very special case. It can at most occur only very locally.

Thus as long as the discussion applies to the Netherlands Indies, with propriety the cases (d) and (e) can remain outside of consideration. But this would not hold good for certain other parts of the world.

* * * * *

If thus far the attention has been directed toward quite pervious soil or toward that sort of parent material (ash, tuff, porous limestone) which still is to become soil,--we may now proceed to consider what happens in the case of poorly pervious soil material. It is true that that material is never absolutely impervious, but yet frequently it is impervious to such a degree that the water movements (a) and (b) take place somewhat differently. And also--as has already been described more in detail on pages 66-67, new phenomena can arise.

If we therefore begin by first viewing all conceiveable possibilities, then it will readily appear which of them will again drop out. We come then to 6 simple cases of water movement, namely:

1. Moving downward, much and rapidly, in easily porous soil........................(N)
2. Moving downward, difficultly and little, in poorly pervious soil..................(n)
3. Relatively much rain water is taken up, but does not pass through impervious soil of great water capacity. During a few dry months this water again evaporates.......(vv)
4. Very little rain water, in easily porous soil. It moistens the soil but in a few days it is again evaporated. An unimportant vice-versa movement..................(r)
   (Rainlessness, without water movement, also falls under this head.)
5. Ascending by capillarity from the ground water with difficulty in poorly pervious soil.....................................(s)
6. Much water easily ascending from the ground water, in easily pervious soil.....(S)

If we suppose that every time during a period of one year two of these cases can occur, then we come to the following combinations:

1--1					
1--2	2--2				
1--3	2--3	3--3			
1--4	2--4	3--4	4--4		
1--5	2--5	3--5	4--5	5--5	
1--6	2--6	3--6	4--6	5--6	6--6

According to the descriptions, from among them a number of combinations of mutually excluded cases are at once to be cancelled, namely:

(1--2), (1--3), (1--5), (2--6), (3--6), and (5--6).

Further, for the Netherlands Indies, the combinations with exclusively ascending water movement and/or as a whole no water movement, can be left out of consideration, since such desert conditions are here unknown. Hence the following also drop out:

(4--4), (4--5), (4--6), (5--5), (6--6), besides also (3--4) and (3--5).

There then remain, in numbers, and symbols:

(1--1)	(1--4)	(1--6)	(2--2)	(2--4)	(2--3)	(2--5)	(3--3)
↓ ↓	↓ =	↓ ↑	↓ ↓	↓ =	↓ ↕	↓ ↑	↕ ↕
N N	**N r**	**N S**	**n n**	**n r**	**n.vv**	**n. s**	**vv.vv**

The last named case occurs properly only at Paloe. Thus for the Netherlands Indies it is an exceptional case. As long as in the field these two cases cannot be easily differentiated, case (2--4) can just as well be taken up under (2--3). Thus there remain only 6 cases; 3 for permeable and 3 for impermeable soils.

As contrasted with earlier divisions, the principal difference of this proposed differentiation is just this that with the good pervious soils **Nr** enters and with the heavy, difficultly permeable soils of great water capacity **n.vv** comes in. This appears especially when questions of soil air arise.

* * * * *

3. According to the <u>entrance or exclusion of air</u> (oxygen) we have to differentiate:

Weathering <u>with</u> access to air, and
Weathering <u>without</u> access to air.

Although it is here stated simply, actually in nature it is not usually so. Even if from the surface downward spacious open capillaries penetrate into the weathered mass or into the soil formed from it, there will be a difference between the soil gas near the surface, which in its composition differs but little from the atmospheric air, and the soil gas (the soil air) close to the deepest end of the capillaries referred to. In the deeper portions the oxygen content is smaller, the carbonic acid content higher.[79] Here we shall not go again into details with reference to the soil gases. We shall only call attention to the fact that although almost always the oxygen decreases downwards, yet in "continuously dry" soils there is still some oxygen remaining over. In order to obtain an oxygen-free soil atmosphere it is therefore quite necessary that the soil be cut off from the atmosphere by a water layer. Therefore the concept weathering without air (oxygen) is practically equivalent to the concept, weathering under water.[80] The latter method of weathering may be called <u>subhydric</u> or <u>subaquatic</u>, in contrast with the first-named <u>subaerial</u> weathering with access of air. They might here be designated briefly with the first letters of their root words (aera (air) and aqua (water)), thus with **ae** and **aq**.

Now in the Netherlands Indies, in particular in the lower tracts, cases occur when the soil in the rainy season stands under water, and in the dry season becomes dry and air enters into the

79. Cf. on this subject: F. Giesecke, Das Verhalten d. Bod. g. Luft. Handbuch der Bodenlehre VI, p. 282-302, where much literature is brought together. See also in this book, pages 68-70.

80. Although there do occur cases in which the water holds adequate oxygen in solution, so that subaqueous weathering cannot be called oxygen-free.

capillaries or cracks to a depth not to be neglected. Now one can take the stand that those two conditions of weathering should be considered separately, but since here prevails a periodic phenomenon, which each year returns without fail, the result over many years brings about something quite specific, quite characteristic, and we can certainly propose the whole as a separate form of weathering by itself. This form of weathering is thus neither **ae** nor **aq**, but the periodical alternation of these two, to which might be given the name of amphibious[81] form of weathering (**am**).

Also the zone which occurs here and there in the soil, which through periodic (seasonal) rising and falling of the ground water level, at one time is aerated and then again is cut off from the air, can be considered to belong to **am**. Different phenomena observed therein agree with phenomena of **am** weathering in the upper layers. However, there are exceptions.

* * * * *

Now previous to going on to the actual description of the ways weathering takes place, and to what they lead, a couple of other important points should first be considered. In the first place the profile should be discussed.

THE PROFILE

No single soil profile is homogeneous from the surface to any considerable depth (say a few meters). It is divided into a number of portions or layers, sometimes called horizons, which in characteristics clearly differ from each other. (See, for example, Figs. 23, and 35-37). It obviously does not lie within the purpose of this book to set out separately all observable differences. Only a few, which apply in this connection, come in for attention.

There are horizons which lose constituents through the water moving through them. Those layers then become leached out, and therefore are called eluvial.

Other horizons will be enriched with new constituents by the water moving through them. These layers are called illuvial.

Still other layers take out certain constituents from the water percolating through and in exchange leave other constituents in their place. Thus such horizons are in some respects illuvial, in others eluvial; hence it becomes more difficult to name them. But in most cases one phenomenon is of considerably greater significance than the other. It is then the predominant one that turns the scale. A few examples might illustrate this.

On a fresh layer of ash situated on a flat hill much rain falls. This rain is almost pure water. As this water penetrates, it dissolves much, so that at first nothing soluble is left behind. The surface layer is certainly eluvial.

In a valley with high ground water, about 20 cm. below the surface there lies some of that same ash. If the rainfall is extremely small, from the ascending ground water which is evaporated, lime and gypsum and perhaps still other salts are deposited at the surface. Such a surface layer is certainly illuvial.

Let us return to the first example and particularly at the time when the surface layer, still eluvial, has just been entirely freed of its bases, so that the entering water already begins to take kaolin along with it as a sol. As soon as this water then reaches the deeper layers where bases are still present, then the kaolin precipitates again, and there is developed an illuvial clay layer under an eluvial layer (red-earth). Out of the illuvial layer the water continues to leach out some bases and perhaps also some silicic acid with it, from which we ought to call the layer eluvial. We consider, however, that the washing out process is now less important and so we retain the name

81. This expression was used for the first time in Mededeelingen van het Proefstation voor de Java-Suikerindustrie (1931), No. 16, "de Genetische Classificatie en Kaartoering der Java-Suikerrietgronden," p. 626. (See also footnote on page 112. However there were there used the letters R, P, and B in place of the symbols **ae**, **am**, and **aq** as here proposed.

Table 48

HORIZON DESIGNATIONS USED BY DIFFERENT AUTHORITIES

Description	According to Stremme	According to Robinson	According to Rueger
Very humous, eluvial, old surface soil covered by a 1 m. thick layer of drift sand..........	A_0	A_1	B
Weakly humous, eluvial, surface soil, in a dry climate, with lime concretions and gypsum....	A_1	B	A
Humus-free eluvial subsoil exposed by heavy sheet erosion..............................	B	A_2	A

illuvial, just as we include all accumulations of iron compounds (ore beds), padas layers, etc. with the illuvial horizons, although we also know (although one neither sees or feels it!) that they are meanwhile exposed to one or another sort of washing out.

Meanwhile it is evident how a single profile can have eluvial as well as illuvial horizons.

So long as we refrain from any ideas about the genesis of the profile, we may describe this profile by simply numbering the horizons from the surface downwards using Arabic numerals 1, 2, 3, 4, etc. or Roman numerals I--II--III--etc.

As soon as such genetic differentiations as illuvial and eluvial enter at the same time, or if one wishes to express, in the designations of the horizons, the humus content, Roman or Arabic numerals will no longer suffice.

Realizing this, a beginning was made with designating the horizons by A, B, and C, but if one consults the international literature about it[82] a very serious confusion still prevails. Thus one worker[83] considers the A horizons to be all the uppermost layers, which possess more or less humus (organic matter). Another[84] indicates eluvial horizons counted from above as A layers, without taking into consideration the humus content. A third[85] calls the "surface soil" simply "A" horizon. However it is generally the practice to use A_0, A_1, A_2, etc., to divide horizons in themselves not homogeneous into different portions. As to what that confusion leads may appear from the above table (Table 48) which has been drawn up according to the definitions set up.

* * * * *

That unanimity is nowhere to be found is probably to be ascribed to the different beginnings which lie at the foundations of the systems. In the namings one worker endeavors to fix conceptions regarding the genesis of the layers. Another believes that "the time has not yet come for this" and contents himself with a mere formal description of the observed profile.

Day by day it becomes increasingly more certain that the first-mentioned method, as followed by Robinson, is the correct one. Besides Stremme and Rueger and other investigators who are inclined to describe the soils more formally have also already let genetic designations slip in into their profile descriptions.

If one once takes up the standpoint of conscious preference for genetic designations of horizons, why should one then hold onto the first letters of the alphabet which but increase the confusion? Only because the Russians at the time did that (and then, perhaps with reason!)? We could

82. L. Rueger, Das Bodenprofil. Handbuch der Bodenlehre V, (1930), p. 1-47.
83. H. Stremme, Gründz./d. prakt. Bodenk., (1926), p. 8.
84. G. W. Robinson, Soils (1932), p. 53.
85. Rueger, l. c., pp. 33 and 46.

just as well, or probably even better, choose symbols with more significance, for example:

for superficial accumulations of organic matter........	**O**	in place of A_o
for surface eluvial soil, with much organic matter.....	**OE**	" " " A_o
for eluvial subsoil with little organic matter.........	**oE**	" " " A_1
for eluvial horizons without organic matter...........	**E**	" " " A or B
for illuvial horizons..................................	**I**	" " " B
for disintegrated rocks................................	**D**	" " " C
for solid rocks, fresh stone (petra)...................	**P**	" " " D

An especial advantage of such designations of horizons as here considered appears in the discussion of erosion, which now follows.

EROSION

At first sight it is amazing how little attention in general is given in European literature to the erosion of the soil.[86] Yet that is explicable, when one compares the intensity of the eroding elements water and wind, working in Central Europe and in other lands of the earth, such as for example in the Netherlands Indies.

By erosion we must understand the mechanical carrying away of soil material, so that from the surface downward the soil profile becomes cut off, truncated, sometimes only a little, yet sometimes to such an extent that almost nothing of the soil is left. Let us consider in the first place

Erosion by water

It is obviously principally through the action of moving, flowing water that mechanical carrying off can occur. The erosive power of flowing water depends upon 1st--the speed of the water, and 2nd--the quantity of water.

The speed is a function of the slope of the land, of the resistance which the water encounters; and also the quantity of water.

The greater the slope, the greater is the component of gravitation, parallel to the surface. For small angles (a few degrees) of slope (alpha) that power is equal to the weight of the water multiplied by sine alpha, and thus just about equal to the magnitude of alpha. The erosive force, however, increases more strongly because when later the water begins to run off with greater speed less water soaks into the soil and thus the quantity of water which flows off is greater. And for that reason too, it flows still more rapidly.

There are two particular kinds of resistance which water meets as it flows along the surface of the soil. The vegetation, especially a network of roots, crawling stems, rosettes of leaves, thick grass, etc., to a great degree retards a shallow stream of water, and prevents it from acquiring much speed in the direction of the slope. But at the same time under vegetation a soil surface is as a rule rougher, more irregular, also more open. Also because of this, the speed of flow is reduced, while at the same time more water soaks in, so the quantity becomes less, and therewith the speed is reduced more. Dense vegetation is thus an important influence in reducing the erosive possibilities.

But also without vegetation the surface of the soil can be flat and smooth, or just as well uneven and rough. For example, a soil rough by nature with many stones on it, may artificially be made smooth by human working of the soil with hoe, plow, or any other tools. Every practical man knows that the retarding influences affecting the flowing off of the water are considerable. Hence it is more important, as the quantity of flowing

86. In Blanck's Handbuch der Bodenlehre, 10 volumes, it is true, there are here and there stated various things about erosion; perhaps a little more about wind erosion than about water erosion; but not even a single separate chapter is devoted to it. That is the case in Robinson's Soils (1932), pp. 62-68.

water is smaller.

The quantity of flowing water however, plays, the greatest role. Not alone because with an increase proportional to the mass, but also because therewith the speed also increases. It is true one finds very different speeds in a flowing layer of water of a definite cross section perpendicular to the direction of flow. The speed is the lowest, and increases upward to just below the surface of the water, so that, whenever one observes flowing water from above, he does not obtain an accurate picture as to the average speed nor as to the speed just along the surface of the soil. But still one may say that the thicker the layer of water flowing over a soil surface, not alone is the average speed greater but also the speed along the soil; moreover with increasing thickness of the water layer and therewith coupled with greater speed, appear clearer and stronger <u>eddies</u> in the water, which whirl up particles of the soil surface and bring them into the higher lying faster flowing water mass. Hence the eddies greatly assist erosion.

Now if vegetation (for example thick grass) lies on the soil then that growth strongly retards the whirlpool action and greatly reduces the erosion. Grasses in a strong stream bend over in the direction of stream flow and so form a sort of protecting cover for the underlying surface, over which the strong stream can glide off without doing much damage. It is true that under the grass cover there exists a water layer, but it flows much less rapidly. If, however, as in many cultivated crops, the vegetation consists of numerous upright rigid small stems, then each of them causes for itself fatal whirlpools, and thus heightens the eroding possibilities, because only slight is the reduction of speed through small increase of resistance.

In case of increasing quantities of runoff water above a certain amount, on bare land, the damaging influence of a rough and uneven surface begins to act to its disadvantage. This is, while the average speed does not increase to above that of a smooth flat surface (it may even remain lower) yet the possibility of erosion increases. Each stone, each clod of earth, is an obstacle, which causes eddies, and therewith promotes whirling up and carrying away of soil material. (See Fig. 7, page 123).

* * * * *

It is now, however, necessary to first distinguish between <u>flat washing off</u> (sheet erosion) and <u>gully</u> or <u>channel erosion (gullying)</u>.[87] Sheet erosion, in the Netherlands Indies called "<u>afspoeling</u>" for short, is the erosion of a flat surface by the rainwater which cannot be easily taken up by the soil. In the beginning the water flows off over the whole surface of the soil in a very thin, but later sometimes already centimeters thick layer.

However, as soon as this water at somewhat deeper points or lines collects together in gullies, channels, brooks, into little ravines and bigger ravines, the flow is limited laterally, and thereby the depth of the water increases, and so the speed.

* * * * *

Let us at first limit ourselves to <u>sheet erosion</u>. It was already said above that this phenomenon begins to make its appearance whenever the soil can no longer take up all the rainwater that falls on it. So this is the first beginning of all erosion, and consequently an important point for investigation.

It is obvious that whether or not the critical point is reached--(and if so, when) must depend on the one hand upon the soil, on the other hand upon the rainfall. The power of <u>soaking up</u> water by the soil is indeed very variable, even for one and the same soil.

Ordinarily this phenomenon is considered as quite simple. It is stated that it depends upon the <u>water capacity</u> of the surface soil, upon how much water can be taken up directly, and further, upon the <u>permeability</u>, how much in a certain time can be taken in, depending upon how fast

87. G. W. Robinson, Soils, p. 63.

Photo by Mohr

Fig. 7. Madioen. View from the Hotel Girimojo at Plaosan. Lahar landscape suffering from sheet and gully erosion, on the west slope of Mt. Lawoe. **V. b. 2 -- Wa. Nr. ae. I.**

the water soaks into the soil.

But actually it is a very complicated phenomenon, for it makes a very great difference whether the soil is somewhat moist, such as is usually the case under forest, or quite dry, such as may be the case in open, bare land.

If the uppermost soil layer is moist, and in most of the cases the deeper-lying layers are also moist then the, so to speak, new rainwater connects easily with the old moisture and deeper penetration can readily take place.

But it is not so if the sun has strongly dried out the surface soil of an open field. Then in place of water or moisture on their surfaces, the particles of the surface layer of the soil have absorbed air as a molecularly thin skin. Relatively more air is absorbed if the particles are smaller and hence, with reference to their mass, have a greater surface. Hence coarse sand has relatively little, fine sand more, ash, silt and still finer soil material the most. And now this may be noted: the first rain drops falling remain lying upon the dry soil in the form of separate drops, covered with a skin of fine soil particles. With the slightest slope of the land these drops roll off, without soaking in.[88] "Unwetability," that characteristic of many sorts of soil to resist becoming moist, is only of a temporary nature. But yet at times it is of sufficient significance to cause much water to run off at the beginning of a sudden heavy shower. If that same rain had fallen slowly as a drizzle, it would all have been taken up by the soil. Time is required for the replacement by water particles of the particles of air, which like a mantle surround the soil particles. If the soil particles are smaller, more time is required, and in this same time all sorts of things may happen, namely, erosion may commence. (See Fig. 15.) Forest soil especially in tropical high forest with much undergrowth, will

88. If water is dropped onto a plate with some flour or talcum powder, then for a considerable time the loose drops remain standing, without further wetting the underlying powder. Spilt water can also be taken up much more quickly with a wet cloth or spoon, than with a dry one. These are analogous phenomena.

practically never dry out that much. Consequently one may safely conclude that whatever falls on it as rain, will at least not find this hindrance to penetration.

There are however also still other hindrances to be indicated. A soil profile is never homogeneous in all its horizons, and is cut off at the upper end by the soil surface. Something can be said regarding the manner in which the surface soil can take up rain water, both with reference to the rapidity and the quantity which it can take up. "Can" is used here advisedly for it is in no sense certain that the soil, if it receives all at once so much rainwater on its surface, also will take it up. For one thing, depending upon the conditions in the soil there always are possible peculiar differences in pressure, positive as well as negative.

Upon what does the soaking up of water really depend? --If we begin by disregarding changes in the soil particles themselves (swelling up, for example), the question is especially regarding entrance of water into capillaries already filled with air. Hence this air must get away, either upwards, or to one side, or downwards, and now all depends upon whether or not this is possible.

In a soil with narrow capillaries which connect with wider passages, in the beginning at least, the air can certainly escape upwards. There is thus opportunity for the suction power of the soil,--a negative suction which draws the water into the soil,--to assert itself, and the surface layer greedily sucks in the rain. But gradually, sometimes quite rapidly, all the capillaries fill up, and also the larger passages and then the surface layer is saturated. Now the air can no longer get away horizontally nor upwards. The only way left is downward. If, as a result of the capillary suction of the next deeper-lying layer, the soil sucks in and draws downward more water, then there develops in the soil air an excess pressure (a positive back pressure) which increases and at a certain point holds up further penetration, unless the air can escape from the subsoil in one way or another. In flat land, however, the air frequently cannot get away, and then sometimes pressure differences have been experimentally ascertained[89] that are greater than would be deduced from the quantity of water which had entered. This phenomenon has not in all respects been adequately explained.

However this may be--if there exists a certain excess pressure under the water layer which has penetrated, then no more water can be added above, although the subsoil may still be bone dry. Then water capacity does not help nor does perviousness. The excess pressure must first be relieved.

Luckily in many cases there still exist direct and indirect "ways out." Direct ones are deep breaks and passages, long hollow root canals, from which the roots have rotted away, passages made by animals such as ants, other insects, etc. The air also finds a direct way out when the land being rained upon is close to the bank of a ravine, for then the air can escape through the bank, while at the same time the ground water in springs or in tile drains can flow away and so make place for air pushed out from above. Or the pressure may be lessened indirectly, whenever the soil vegetation uses air (oxygen), and gives off carbon dioxide into its place. This latter gas is much more soluble in water than oxygen and moreover can be fixed as carbonate.

But still it is worthwhile to realize that it is possible that in a quite permeable soil under a heavy rainfall, only relatively little water can penetrate into the soil. In such a case it is of the greatest importance that an opportunity exists for the air to escape from the deeper layers.[90]

Now this will be more apt to take place if some time is available for it. Such a shutting-off sheet of water in the uppermost layer of the soil always has a lower surface which from the nature of the case is not uniformly flat, just as the soil is never completely homogeneous. Here the water penetrates somewhat deeper into the soil, there somewhat less; and the more

89. Cf. J. H. Thal Larsen, Meded. Landb. H. Sch. Wageningen 34, Verhand, 5 (1930).
90. If, in order to reduce erosion, one wishes to facilitate the penetration of rain water, then this current of thought gives suggestions about it. More about this later, in the applied soil science.

the first occurs, the sooner at the shallower point the water is pushed back by the excess pressure of the air. In short, where the soil does not have channels for the escape of the air many times it creates its own. If that succeeds fairly easily, the phenomenon of shutting off recognizable by the eye by the appearance of a water layer on the surface of the soil, occurs less often.

For the penetration of water and escape of air, more time is necessary if the capillaries are finer and the resistance is greater. This once more explains what everyone after all, knows already, that a deep soil of great permeability (that is to say, with wide capillaries and passages) can take up a heavier rain than a soil with narrow capillaries, i.e. with a small permeability. And further, the same quantity of rainwater, falling during a longer time, i.e. with a low intensity, is better taken up than when it falls rapidly in a short time.

Now if from this last-mentioned viewpoint, we examine the rainfall in the Netherlands Indies in comparison with that in Central Europe, then it appears[91] in the first place that the greatest intensity of the rain, calculated per minute, is not so much greater in the tropics than in the temperate zone (see Table 49):

Table 49

Duration of Maximum Rainfall

		5	15	30	60	
Calculated over a time of		5	15	30	60 minutes	
The maximum rainfall per minute	In the Netherlands Indies.....amount to	3.4	2.6	2.1	1.5	mm.
	In Germany	2.9	2.3	1.6	0.9	mm.

The longer, however, the heavy rain continues the more the tropical figures will exceed those of the temperate region. In the lowlands of Germany for 24 hours there has never been recorded a greater maximum than 250 mm., in the Central European mountains more than 350 mm. On Java, however, there has been established a maximum of more than 600 mm., and, according to Boerema[92] "for a great majority of the stations the daily maximum lies between 200 and 300 mm."

For all that, there are not more hours of rainfall a year in the tropics,[93] on the contrary, as shown in Table 50, page 126, there are fewer.

The last recorded contrast, however, does show how in the tropics there are 20 times as many total hours of 10 mm. (and higher!) rainfall as in Central Europe; and those are just the heavy rains, which the soil cannot absorb, no matter how pervious it is.

Now if we calculate the rainfall per rainy hour we obtain Table 51 (page 126). Then, if the rain always fell at a uniform rate, from a soil which has a permeability of about 5 mm. per hour, nothing should need to run off--all could quite well be taken up. But this is not the case. We saw that during 40.7 hours per year at least 10 mm. fell. That amounts to at least 407 mm. (actually of course much more), of which we could expect but about 200 mm. would be taken up; the rest presumably flows off. The balance of the annual rainfall (1815 - 407) = 1,408 mm. fell in (357.1 - 40.7) = 316.4 hours, thus averaging at most 4.4 mm. per hour. And yet even this would not all be taken up, for in this total there are included still many hours of from 5 to 10 mm. rainfall per hour!

Meanwhile we may accept as quite reasonable the possibility of sucking in about 5 mm. rainfall per hour. How greatly divergent the permeability and therewith the possibility of the soil soaking in the

91. Cf. C. Braak, Het Klimaat v. N. I., I, 156.

92. J. Boerema, Grootste regenval i. verb. m. waterafvoer, Waterst. Ingen. (1918), No. 7.

93. Braak, l. c., p. 481. According to Hellmann: Sitz. Ber. Preuss. Akad. Wiss., 27 (1923).

Table 50

COMPARISON OF RAINFALL DURATION IN GERMANY AND IN JAVA

Average number of rainy hours

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Potsdam...	70.8	80.6	62.3	46.8	38.3	32.2	41.8	45.9	43.9	35.9	77.7	80.5	656.7 hours
Batavia...	74.6	51.2	35.8	24.5	21.6	12.9	9.6	7.4	11.6	20.4	39.7	47.8	357.1 "
Average rainy hours during one rainy day													
Potsdam...	4.3	5.0	4.1	3.2	3.0	2.4	2.6	2.7	3.2	2.6	4.2	4.7	3.5 "
Batavia...	3.1	2.2	1.8	1.7	1.7	1.1	1.1	1.0	1.3	1.6	2.1	2.3	1.8 "
Average number of total hours of 10 mm. and more rain													
Potsdam...	---	---	---	---	0.7	0.7	0.3	0.1	0.2	---	---	---	2.0 "
Batavia...	8.4	5.6	3.8	3.0	2.8	1.9	1.2	1.2	2.1	3.2	3.5	4.0	40.7 "

Table 51

RAINFALL PER RAINY HOUR IN BATAVIA

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average rainfall..	305	320	212	139	108	91	67	43	69	119	143	199	1815
Average number of rainy hours.....	74.6	51.2	35.8	24.5	21.6	12.9	9.6	7.4	11.6	20.4	39.7	47.8	357.1
Rainfall per hour.	4.1	6.3	5.9	5.7	5.0	7.1	7.0	5.8	5.9	5.8	3.6	4.2	5.1

Table 52

PERMEABILITY OF DIFFERENT CLASSES OF SOILS

	Permeability, calculated in mm. height			
	Per second	Per minute	Per hour	Per day
Stones, gravel..............	>1	>60	>4,000	>100,000
Coarse sand.................		60 -0.3	4,000-20	100,000-500
Loamy or ferruginous sand...		0.3-0.0015	20-0.1	500-2
Sandy loam to loam..........			0.1-0.0004	2-0.01
Heavy loam to clay..........			<0.0004	<0.01

water may be, appears from Table 52, (page 126) calculated from data of Zunker.[94]

* * * * *

From this it appears that only gravel and coarse sand,[95] are able to take up showers of 20 mm. per hour. No other sorts of soil can do this. As to the heavier soils their ability to take in rain water is extremely limited. Once such soils are wet and saturated (for example from previous days), then even a little shower of only 3 mm. will practically all flow off.

On the other hand at the end of a long dry period in impervious clay soil the net-work of small to very large cracks can be so important that the first heavy shower can completely disappear into them. Later, if all that water is taken up in the clods and the soil has swollen, the soil closes up completely and practically nothing more goes in, perhaps not even 1 mm. during a rainy period of 100 days. At a depth of a few meters below the zone of cracking there is practically no water movement and only during extremely long periods of time, which may be measured in geological terms, is perhaps a change to be observed.

There are available but very few experimental data regarding permeability for the Netherlands Indies. Using a method which he slightly modified from that of Burger[96] Becking[97] has determined the permeability of a number of soil types under certain crops and certain methods of cultivation. The great number of determinations which Becking made show how sensitive those determinations are to small soil differences. His figures, determined for every 15 minute period, calculated the average amount per minute to be about 3 to 8 mm.,[98] with a minimum of 0.07 and a maximum of 23 mm. Later Japing[99] made similar investigations and for sandy soils found 12 to 50 mm., while for the brownish red Buitzenzorg lixivium soil, depending upon the nature of the crop and cultivation, from 0.06 to 39 mm. From this it is obvious what an enormous difference it makes whether the vegetation consists of a (presumably quite old, solid) grass sod or of a stand of Crotalaria anagyroides (on a doubtless previously cultivated soil). Of the heavy showers not much can run off from under the latter cover, but in the solid grass sod but little penetrates--almost all runs off.

It is thus reasonably safe to summarize: a large part of the rain water of by far the greater number of the Netherlands Indian showers runs off over the surface of the greater number of soil types--(sand and gravel soils without finer components seldom occur here). Viewing the question from this angle, there is thus much chance for considerable erosion. Now the question may also be viewed from the other side, that of the soil itself.

A soil may or may not have a tendency to erode. Of one soil the particles are moved in even extremely small streams of water, from another soil even a brisk stream loosens scarcely anything. To what may this be due?--

While it is true, as has already been said above, that in Europe not much research has yet been devoted to this question, in America a good deal has already been done.[100] The treatise "Soil Erosion a National Menace" by Bennett and

94. F. Zunker, Das Verhalten d. Bod. z. Wasser., Handbuch der Bodenlehre VI, p. 173.
95. And also the soils in the Netherlands Indies which are granulated to such a degree that they behave as coarse sand. They will be considered later on. See p. 150.
96. H. Burger, Physik. Eig. d. Wald. u. Freilandböden., Mitt. Schweiz. C. A. f. forstl. Vers. w. XIII (1922).
97. J. H. Becking, De Djaticult. op Java., Diss. Wagen, (June 1928), p. 151; idem in: Meded. Proefst. Boschw. Buitenzorg, No. 22 (1928).
98. L. c., p. 278 and 222.
99. H. W. Japing, Doorl. onderz. v. gronden-Tectona, 24 (1932), 793-824.
100. Since this was written the enormous and extremely important Soil Conservation Service has been developed in the United States. The extent and diversity of the experimental work on all phases of soil erosion and methods for its control are overwhelming. It is as yet hardly advisable to attempt any survey of that work here at this time. --Translator.

Chapline[101] in 1928 gave a boost there to soil erosion research. In 1930 there followed a publication by H. E. Middleton,[102] wherein were traced the connections between a number of soil characteristics and erosion. This paper can be considered only as a beginning in the right direction. In order to motivate this conception it may be pointed out that in that study, sheet erosion and gullying were not kept apart. Then Middleton himself mentions a number of characteristics which he thought might perhaps be considered of influence but have not yet been studied. While a number of others, which were investigated, showed no relationship to susceptibility to erosion (page 13). "It is possible that the plasticity number would be more significant than the lower liquid limit. The percolation rates, if available, would doubtless be of value." Further he selected also as factors those which in one way or another have something to do with susceptibility to erosion, the quantity of organic matter in the soil, "the silica-sesquioxide ratio," and the total exchangeable bases.

Typical of the kind of investigation which must prevail as long as one still continues to be a stranger to the essentials of a phenomenon, is the determination of a value or quantity which has been supposed to be related in some way or another to the erosiveness, for example, the determination of the "slaking value." This is the time in seconds, which a disk of the diameter of a dollar and double the thickness of one, formed from the soil to be studied, and thereafter dried out, requires to fall apart, when it is laid in water upon a ring of thin sheet copper, approximately 0.5 cm. high, and of about the diameter of a 50 cent piece. Middleton says cautiously that this "slaking time" seems to have a certain value, and that it seems to be higher for "non-erosive" soils. But the experimental factual material was as yet quite inadequate for more definite conclusions.

This "slaking value" also increases with the content of colloids. Therewith, according to the opinion of this school, the heart of the question is touched. It seems that all of the factors summed up above which are of influence upon the erosiveness are closely related to the colloids of the soil, and related not only to the quantity of colloids but also to their nature.

If on the basis of the experimental data (alas! it is yet but small) we endeavor to obtain a clear conception as to what occurs in sheet erosion then, in order to make a beginning, we might well say: if the soil particles in the surface soil are held together by only relatively weak or negligibly small forces, the particles can easily be carried along by a flowing and eddying stream of water moving over them. In other words, a surface soil consisting of such loose particles is erodable, is subject to washing off.

Gravel and coarse sand are examples of soils with negligibly weak forces of cohesion; their erodability thus depends entirely upon the water stream, or more precisely, upon the speed of the stream and the occurrence of eddies in it. Yet these soil components as a rule are not otherwise moved and transported except by rolling. Thus only by rapidly flowing water, and down quite steep slopes.

Fine sand and silt, if they are really free of clay are more readily subject to erosion as the diameter of the particles becomes smaller. But on the other hand, as the particles become smaller, the power of attaching themselves to each other increases. There is thus reached a limit where the increase of the mutual drawing together and holding fast surpasses the decrease of the resistance against washing off, due to gravitation. Represented by a graph, those two counteracting forces affecting erosion oppose each other, thus forming two curves (Fig. 8, page 129).

Representing it all very schematically, the actual resistance against washing off is then the sum of the two coordinates. Thus, the middle of the curve is shown by the broken line, and the left and right limbs coincide with the higher parts of I and II. Obviously neither the right limb of I nor the left limb of II compose a part of the combined curve.

With regard to the curve I a little

101. H. H. Bennett and W. R. Chapline, U. S. Dept. of Agr. Cir. No. 33 (1928).

102. H. E. Middleton, Properties of Soils which influence soil erosion, U. S. Dept. Agr. Techn. Bull. No. 178.

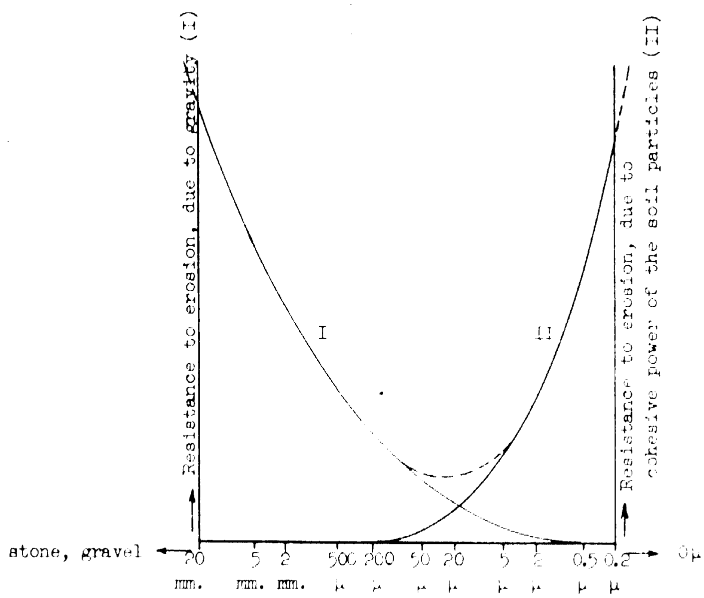

Fig. 8. Resistance of soil to erosion as related to particle size, gravity and cohesive power of soil particles.

difference of meaning exists. In reality of course it rises up much steeper toward the left, since the transportability of rolled particles is inversely proportional to the 6th power of the diameter. Provided that they lie "loose," particles between 50 and 5 mμ are also taken along by even an extremely weak stream of water.

As to the actual data for curve II, we are entirely floating in a fog; dropping into the midst of the problem, we ask: Upon what does it depend?--It points out the power of cohesion, which increases with the decreases in the __size__ of the particles, in the same manner as the surface of the particles increases with respect to the volume. If one thus identifies the cohesion with the surface power of the colloids, at once the name "colloids" awakens the conception of __sticking power__ (provisionally still without numerical magnitudes)--without difficulty the sticking power is associated with the "slaking value," the resistance against falling apart in water. And it becomes very plausible that this "slaking value" increases with the colloid content of a soil, because therewith also the sticking power, the cohesion, and the surface action of the colloids becomes greater.

At the same time the __form__ of the colloid particles must also play a role. If the particles are (again schematically) not spheres but having the same volume are scales, or plates, then their surface is relatively much greater, and so is also the adhesive power. It should be added that the finer the kaolin-like minerals are, the greater cohesiveness they exhibit, and thus "colloidal white clay" is very resistant against erosion. If for such material the so-called Atterberg figures[103] are determined then the clay appears to possess a high plasticity and a strong power of adhesion. If, on the contrary the kaolin is crystallized to kaolinite scales with dimensions of about [illegible] to 20 mμ, then the resistance against erosion is small (Fig. 8). This is well illustrated in the tin mines of Banka and Billiton, where layers of kaolinite "loam" several meters in thickness can easily be broken up with a jet of water and washed away.

Besides thus becoming coarse through crystallization, the same colloid can, as a consequence of the exchange action with electrolytes, go over from a most extremely dispersed condition into a __flocculated__

103. According to Meded. Labor. v. Agrogeol. en Grondond., No. 1, Dept. L. N. H. Buitenzorg (1915).

condition. It takes a very long time for clay to sink out of water which is very poor in electrolytes. The clay which is then strongly dispersed gives rise to a hard firm clay layer with a so-called "single grain structure." An illuvial clay layer, originating from the soil horizons above, which are poor in electrolytes also has this same structure. When through topographic changes it is exposed subsequently to flowing fresh water, or even to sea water, such a clay layer is very resistant against erosion. This resistance is, for example to be observed in river banks (see Fig. 9), along the north coast of Krawang, where the surf breaks upon it, and in the Netherlands on the "clay loam" of the Zuiderzee cut-off dike. But, if the highly dispersed clay together with its fresh water flows into the sea, then the salt in the sea water flocculates out the clay, and it sinks in coarse floccules, mixed, as a rule, with calcareous organisms. "Marine clay" of this sort is by no means so solid as that described above. As long as there is salt in it, it is reasonably porous, while the fresh water clay layer may safely be called impervious. If, however, through an elevation of the sea floor, true marine clay is elevated above sea level, and so is exposed to erosion, then it appears to have much less resistance against erosion.

Moreover we have to take into consideration definite changes in the clay sinking in sea water, that is, with respect to changes in its ion content; changes which are exactly the ones to bring about that flocculation, namely, the replacing of H ions by Ca, Mg, K, and Na ions. Conversely we may also suppose that all colloid-rich soil which exhibits a high degree of saturation of bases is more flocculated, more coarsely dispersed, is less solid, and is thus more subject to erosion, especially to certain types of gully erosion. (More about this on page 132).

The statement of Middleton that "The non-erosive soils reported have all developed under conditions of high annual

Photo by J. G. van Setten

Fig. 9. Palembang. High river bank along the Moesi, with the following profile:

oE = 1--2 ft. Humus, dark brown surface soil. Crumbling but bound with roots.
E = 5--8 " **al--He.NN.ae.2/3.** Crumbly, brown to red. Dry wash!
6--8 " Flecked transition.
E + I = 4--6 " **al--He.NN.am/aq.3/4.** Heavy, slippery clay, pale with flecks; less subject to erosion, hence bulging out.

rainfall (40 inches or more), which indicates a low silica-sesquioxide ratio," corresponds rationally with what has been said above. Indeed in the districts with a very humid climate the leaching out of the bases is important, as the colloids have an outer mantle with many H-ions. All particles are negatively charged, the floccules break up and the soil becomes highly dispersed. The enveloping by water molecules is considerable and surrounds the particles as a slimy skin does a fish. One can thus take for granted that not only the permeability is small, but also the erodability. The flowing (rain) water slides off over the soil.

But we have already seen repeatedly that in a warm moist tropical climate the relative amounts of sesquioxides increase as compared with the silicic acid, thus with the picture just sketched also belongs a low $\frac{SiO_2}{M_2O_3}$ ratio. However, the quotation from Middleton is still incomplete and therefore inaccurate. It is true that sesquioxides can be present in different forms in the soil 1st as colloidal hydroxides, and 2nd as crystallized, coarsely dispersed constituents.

Colloidal iron hydroxide is brown. It is electro-positive when it occurs together with colloidal kaolin or with colloidal organic matter (humus) which are both electro-negative. In these cases there is, as a rule, a mutual flocculation, with the floccules again clumping together to form little lumps, making a mass which is pervious to air and water. If, on the contrary, the iron oxide is coarsely dispersed, crystallized as brown iron ore (still brown), goethite (already red) or hematite (blood red), then it does not have a flocculating and granulating action in and on the clay (which in itself can remain a white colloid). In case the colloid is poor in bases, it is excessively dispersed hence impervious to air and water. This is the explanation why juvenile brown earth is so pervious, but when saturated with water quite easily erodable. But senile red earth is more difficultly permeable and is less subject to washing off.

The same applies to aluminum hydroxide. When colloidal, next to brown iron hydroxide, it promotes the flocculation. But crystallized as hydrargellite scales, or as diaspore, it doesn't have much effect, and finally allows the kaolin colloids present to lie intact and impervious.

The sentence from Middleton ought to be revised to read as follows: "Soils with a low $\frac{SiO_2}{M_2O_3}$ ratio, i.e. soils of warm humid regions, are 'non-erosive' if the iron oxide occurs in one or the other of the red forms. If however the iron is brown or brownish yellow, and hence flocculated and pervious, under a rainfall of low intensity the soils are only slightly erodable (since they are pervious and suck up the rain). However under intensive rainfall (heavy showers) these soils erode seriously, because the grains lie loose, and this looseness is proportional to the absorbed bases that are present."

Let us consider next what Middleton says regarding the so-called "dispersion ratio." This quantity, expressed in percentage, is the ratio of the quantity of particles which are smaller than 50 mμ, (i.e. smaller than sand) to the quantity of particles below that same limit, but after thorough dispersion and thus the destruction of all crumbs and floccules by shaking in an alkaline medium (very dilute ammonia, NaOH, or other suitable deflocculant).

It is clear that we here have to do with whether or not the soil is flocculated and the resulting crumb structure. All fully dispersed soils occurring in nature give a dispersion ratio of about 100%. The lowest figures are of soils with a high colloid content, soils which are flocculated and granulated in such a manner that they behave almost as sand. In Central Europe the denominator of the fraction is seldom above 50%, while in many Netherlands Indian soils it rises up to 95% and more. The numerator is very variable, but for some Indian soils[104] it is strikingly low, only a few per cent or even still less.

Now Middleton says[105] "The

104. Cf. E. C. J. Mohr, Ergbn. mech. Anal. trop. Boden., Bull. Dépt. Agr. Ind. Néerl., No. 47, p. 17.

105. H. E. Middleton, l. c., pp. 13-14.

dispersion ration is probably the most valuable single criterion in distinguishing between erosive and non-erosive soils. It is logical to assume that soil material which is easily brought into suspension is more readily carried away by run-off water. .... It is probable that on the basis of this property alone, soils with a dispersion ratio of less than 15 may safely be classed as nonerosive." But the question is, however, not quite as simple as this. Reference might be made to the very extensive soil type in the Netherlands Indies, that is brown volcanic soil, rich in iron, very pervious, and non-plastic. But this may be dispersed to more than 90 per cent "colloid," while if the soil in its natural state is placed in water more than 99 per cent sinks as "pseudo- or false sand."[106] The dispersion ratio amounts thus at most to about 1 per cent. And the erosion?--Small showers are readily absorbed but heavy rains cause serious erosion. Especially the humous surface soil washes off as if it were sand of relatively low specific gravity.

Middleton has made an attempt to introduce a correction through still another factor $\frac{\text{Moisture equivalent}}{\text{\% colloid}}$ to divide the dispersion ratio, and so to arrive at an "erosion ratio." But as yet there is not available a very great quantity of experimental material, so that thus far no significance can be ascribed to this factor. Moreover, the sense of the factor referred to is far from obvious, since the numerator is a sort of minimum water capacity, obtained in a very arbitrary fixed manner by pressing water out of a saturated soil or throwing it out in a centrifuge, and the denominator the percentage of particles, smaller than 1 mμ.

One may thus say that the theoretical as well as the experimental investigation concerning the erodability of a soil is still entirely embryonic, but that the importance of the question makes intensive work on it highly necessary.

* * * * *

Now let us consider various matters relating to gully erosion, which in contrast with sheet erosion ("afspoeling") might well be called "washing out" (uitspoeling). Yet this latter term is not preferable, since as a rule the phenomenon of gully erosion goes together with the so-called "caving off" of the walls or banks of the stream. Thus gully erosion really includes two phenomena.

This is not the place to discuss the whole complex of phenomena which may be observed on and along brooks and rivers. If one is interested he should consult works on geomorphology. We limit ourselves here to the gullies and ravines in which the water flows, before it reaches a creek bed or river bed. Thus the water movement referred to is always temporary or intermittent in time, it lasts as long or just a little longer than the shower lasts, but not longer than that.

The great difference between the two forms of erosion is that here in gully erosion both the depth of the stream of water and the speed are greater; therefore coarser soil constituents such as sand, gravel, and stones which are unaffected by sheet erosion are moved by gully erosion (Fig. 10, page 133). In addition, these coarser constituents working with the water scour out the gully much more and much deeper than water alone could do it. Also the gradually developing side walls become scoured out, and whenever the deeper layers of the soil are more erodable than those above, there develops above the rapidly flowing water an overhanging edge, which of course some time or other breaks off, and falls into the stream and is disintegrated into its constituents (Fig. 17, page 137).

Gully erosion thus works more intensively than sheet erosion, not only downwards, but also horizontally, continually widening the gully itself (Fig. 11, page 134). Therefore, land with surface soil which is quite resistant against washing off, can gradually be deprived of many layers of subsoil plus surface soil. It is sometimes appalling how, in a few years, even in one heavy rainy spell, erosion can devastate what previously in as

106. The very expressive term "false sand" has been developed from the earlier expression "pseudo-sand," which was first used in the literature by: J. J. B. Deuss, Meded. Proefst. Thee., No. 89, (Batavia 1924), p. 12.

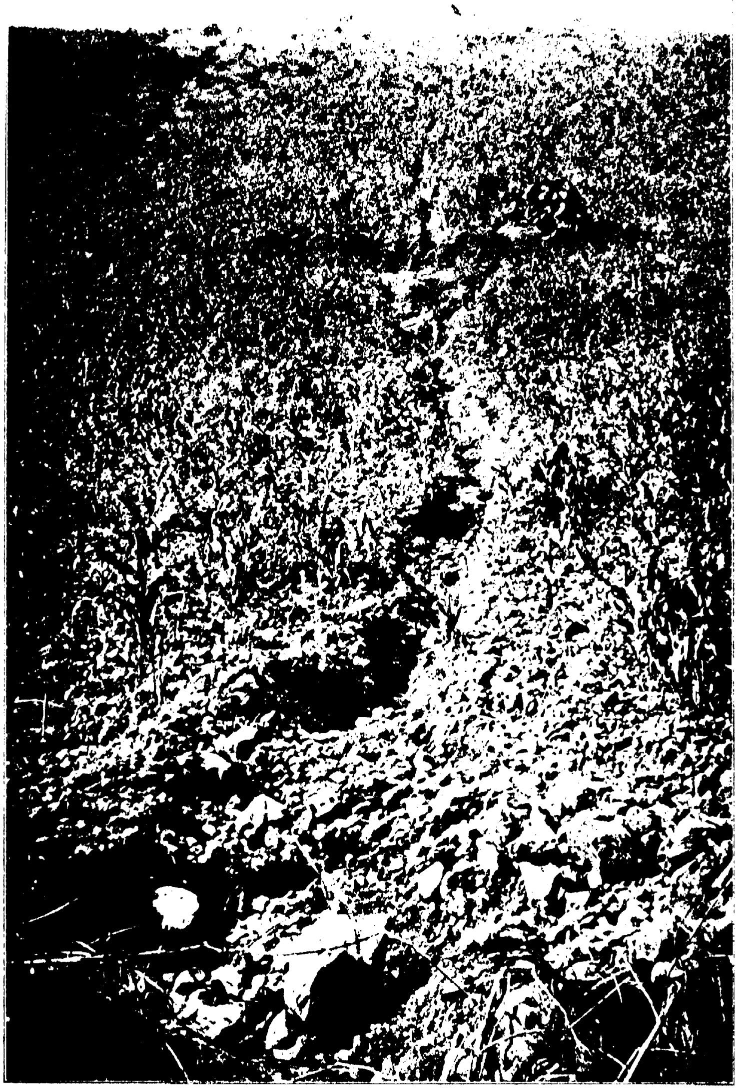

Photo by Ph. van Harreveld

Fig. 10. East Java. Deforested slope. In the Boedoean sugar central district, south from Meraan village. Erosion resulted from a single night's rain of 100 mm. On the top: black earth. V---He.nvv.am.2.

many centuries was worked up or developed under forest as surface soil and arable ground. (See Figs. 12, page 134; Fig. 13, page 135.) For as a matter of fact gully erosion does not continue in the relatively small gullies with which it began, but continually eats out sideways and headwards. Especially is this true of loose material, such as frequently occurring areas of young volcanic ash and sand in the Netherlands Indies. Here gully erosion is more important and dangerous than sheet erosion, since often times the surface soil is more bound by weathering colloids and is also covered with vegetation. However, when a crumbly, humous surface

Photo by G. Bremer

Fig. 11. East Java. The sand sea between Bromo and Batok. Gully erosion in practically fresh ash. Very temporary terraces. Beginning of vegetation.

Fig. 12. Siantar, East Coast of Sumatra. Destruction in a tea garden, brought about during a single rainy night, through sheet erosion followed by gullying. Soil: brown lixivium upon a porous liparite tuff: Va. I -- Wa. NN. ae. 2.

Fig. 13. Siantar. East Coast of Sumatra.--Ravine in the irrigation district Bandar Meratoer, originating as a consequence of the erosion of percolating water, in a few hours time! The entire ravine is about 200 m. long, averages 20 m. wide, and in some places is 2 m. deep. Typical gully erosion in loose liparitic tuff.

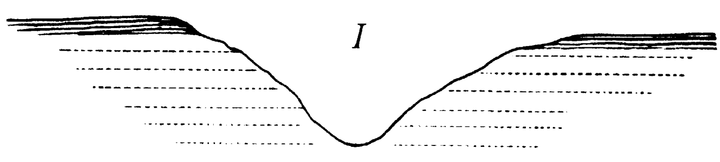

Fig. 14. Erodability of the uppermost layer (arable ground) is greater than that of the lower layers which sometimes remain exposed. Consequently, a bare, undulating surface exists. Surface erosion (washing off) is much more serious than gully erosion (washing out). (See Fig. 15.)

soil lies on a solid, slightly erodable subsoil, the conditions are exactly reversed. Here sheet erosion is the most severe, for the surface soil washes off and leaves the stiff subsoil in a relatively untouched condition.

In the field, one can readily evaluate the land as to erodability. On looking along the gullies, the little and big ravines, and noting the profiles exposed in them one can observe all kinds of conditions: hard layers (ore, tuff, padas) project out; loose sandy layers recede. Also illuvial clay layers are prominent and in this way show their resistance against erosion. In subsequent portions of this work reference will be made to a number of concrete examples which clearly demonstrate the above features (see Figs. 14-18).

Under the first type of gully profile there has just been mentioned the phenomenon of bulging out which sometimes occurs instead of breaking off. This

Photo by Mohr

Fig. 15. Soerakarta. Near the Tjemoro river, to the north of Kalioso. Sugar cane on black earth. Where the people are standing is a horizon of brownish red iron hardpan. Lower: again black earth on acid tuff. The slope toward the river, cut away by surface erosion.

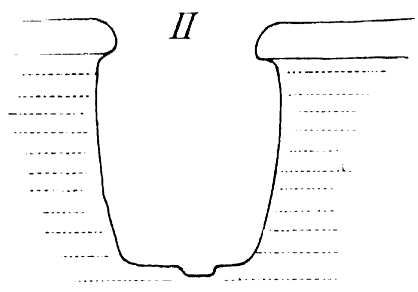

Fig. 16. Uppermost layer, (arable ground) resists erosion better than the lower ones which are very easily washed away. Consequently small deep ravines with caving occur. Gully erosion is more vigorous than sheet erosion. (See Figs. 12, 13, 17-19.)

bulging out or convexity occurs with loams and clay of marine origin, but not with loam and clay deposited from fresh water. There has previously been stated (p. 129 ff.) the difference in stability between these two kinds of clays and loams. The two differences must be related to each other, and with the difference that fresh water deposits, as here meant, are deposited in single grain structure and unsaturated with bases, while the marine deposits are precipitated as floccules with a certain

crumb structure and to a large degree are saturated with bases. If now these former marine sediments, elevated to land, come in contact with much fresh water (rain), then they tend to bulge out and slide. What actually happens here has not yet been investigated nor explained though it has been abundantly demonstrated by experience. And this experience has further shown that the bulging out of gully banks and slopes toward the rivers is the occasion for considerable erosion phenomena,[107] which in a short time can widen out even relatively shallow gullies and ravines to broad valleys with slight slopes. The part of the slopes which slides off into the river or into the temporary water stream does not fill the valley up, but is disintegrated astonishingly rapidly so that the silt content of rivers which flow through

Photo by Mohr

Fig. 17. South Bali. Ravine between Gianjar and Kloenkoeng. Thick layers (40-75 m.) of ash tuff. V. b. I. but only loosely cemented. In the center: a large piece caved off falling into the bottom, is now being disintegrated by the water; great boulders remain behind, while the fine material is washed away.

107. Cf. L. Rutten, Over denudatiesnelheid op Java, Versl. Kon. Akad. Wet. Amst. Wis-en Natuurk. afd., XXVI, (1917), p. 920-930.

Photo by S. J. Wijmenga

Fig. 18. Sumatra's West Coast. Karbouwengat at Fort de Kock. The vertical wall, from which enormous masses of tuff break off and dash downwards. The height visible here is more than 100 m. The soil at the top is but 2 feet deep.

Photo by J. M. Baron van Tuyl van Serooskerken

Fig. 19. West Java. Cheribon. The Tji Manis river cutting into horizontal marls with interbedded layers of lime. The black earth lying on this has strongly bulged out and eroded.

such a terrain can rise to more than 40 g/l or kg/m^3. We will have more to say about this when speaking of transported material and the allochthonous soil types formed from it.

* * * * *

Erosion by the wind

These words involuntarily bring to mind deserts and sand storms or sand dunes along the sea coast, but always sand. Yet there are to be observed many phenomena of wind erosion on soils which do not fall under the class of sands. Also it is not necessary for definite storms to arise to cause such erosion, as even a moderate wind can transport much soil material to other, sometimes far distant, places.

Drying out is the first condition for this erosion. Whenever the adhering and slightly binding water evaporates, sand grains at once become separate from each other. Then the wind can blow the grains, first by rolling them, then with a stronger wind the grains hop and jump, and are finally taken up into the air. Of course in this movement the most important point is the size of the grains. With a moderate wind, all the finer material is sorted out from a coarse sand, and deposited somewhat farther on. Wind deposits such as löss for example are as a rule found upon sampling to be of very uniform grain size, since such deposits have for the most part been developed by a selection process, which takes place over an area of as many square kilometers as selection by water over square meters.

Fresh volcanic ash, once it has fallen after an eruption, does not become such an easy prey to the winds as does sand, for even after a single shower the ash very easily becomes packed and hardened into tuff. Ash-falls, occurring in a completely rainless period, however, are, to a great extent, picked up by strong dry winds and, after sorting, are deposited elsewhere.

But there are other kinds of soils which demand particular attention; sorts of soils which consist for the greater part of colloids which, upon drying out, shrink and then crack. Now there are those which crack

Photo by H. Witkamp

Fig. 20. Soemba. View from Palakadoki, on the eastern edge of the Kanatang valley, looking toward the west south west, over the bare limestone and marl plateau of central Soemba. In the foreground all the soil has been removed from the marl through wind erosion in the dry season and sheet erosion in the rainy season. Only in the valleys does the soil remain and the vegetation grow through more than one year.

into great blocks, like tiles, lying side by side with wide joints between. But there are others which crack and break down further, into small grains which are full of minute cracks. In this way a kind of sharp-edged crumbly "pseudo-sand" forms which, as the wind rolls it about, appears to possess little internal cohesion, and is thus rapidly broken up into a powder.

There are two constituents which give to strongly colloidal soil these characteristics: (1) iron oxyhydrate, and (2) organic matter in the form ordinarily called humus. The soils subject to wind erosion are thus especially the brownish red soils, and of them particularly the humous dark brownish black surface soils. But also the strongly humous forest soils which through deforestation are subject to strong drying out and blowing away (black dust soils).

For completeness it may be stated that also a high lime content, absorptively combined, imparts to a soil similar characteristics. Especially in the southeastern part of the East Indian Archipelago, where in the long dry monsoon the fierce southeast wind blows constantly. Each year all the freshly formed soil is blown away from the bare limestone mountains and deposited in the low valleys. Thus on the ridges and hills no "soil profile" can develop, since before there can be a soil which can carry vegetation and which in its turn can hold the soil fast, all the soil material formed has been blown away (see Fig. 20 above).

This is perhaps the best place to call attention to still another erosion phenomenon which, although the wind plays no part in it, is yet a result of similar causes.

If in any sort of gully, or cut--a result of gully erosion such as above described or a steep river bank, or a road cut, or an excavated ditch--such a colloidal soil, rich in humus or in iron oxide (hydrate), is strongly dried out by direct rays of the sun, we can see even on a calm day a continuous stream of soil particles "raining" off from the steep banks. This

Photo by Mohr

Fig. 21. West Celebes, just south from Donggala.--Red lixivium from old basic eruptives: **V.b.--He.Nr.ae. 3.** Under the root cover follow **OE**, about 1/2 m., very subject to "dry wash." Then 2 m. of **E**, somewhat more resistant but washed by gully erosion, which in the paler layer following just below is at first greater, due to its greater content of sand and more granulation.

is what the Britishers call "dry wash"; a phenomenon that can widen a gully sometimes remarkably quickly. (Cf. Fig. 21.) If, for example, after a shower, water is flowing through the gully, then all the material which has "rained" downward becomes easily and quickly mixed with the water, and is irretrievably lost to the terrain from which it came. Now it is remarkable that in this way soil can be eroded which in a continuously wet condition presents great resistance to erosion. But it should also be remarked, that the "dry wash" can only occur in those places where a steady drought alternates with strong rains, and for that reason this phenomenon is excluded during periods of continuous rains and an overcast sky.

* * * * *

Finally there still remains to be mentioned the relation between <u>erosion and ground water</u>. By surface erosion (sheet erosion as well as wind erosion) the distance between the upper surface of the soil and the ground water continually diminishes. But as a result of gully erosion, especially if the gullies deepen into ravines and deep valleys, the ground water level falls more and more and therewith its distance from the general land surface is increased. When, by sheet erosion, more material is deposited in the valleys than is carried away by the water flowing out, the ground water level may even be raised.

What influence do such ground water changes have upon the soil?--Generally speaking it may be said that the soil profile becomes modified. Layers, which originally were above the ground water, now, because of the rising of the ground water, lie under water. Thus, while formerly the material could weather in the presence of air, it is now deprived of air. Also the reverse may occur. Layers which used to weather under water are, with the fall of the ground water level, left dry. Thus the air has access to them, with all the consequences that such access implies.

So, through gully erosion, illuvial horizons of the soil profile, at some distance from the gully, can be changed into eluvial horizons. This may occur at the beginning, somewhere near the middle, or at the end of the weathering process.

Thus not only externally, through "decapitation" or truncation, may a weathering profile become altered by erosion, but that can also occur internally through alteration of **I** layers into **E** layers, **ae** horizons becoming **aq** horizons, etc. The reverse may also happen. Under no consideration can we overlook these possibilities.

* * * * *

4th. The stage in the weathering process.

For the tropics, on the "frame" of the three above-mentioned main features:

1. the elevation zones, thus the temperature zones, or belts,*
2. the water movement in the soil,
3. the presence or absence of air,

and therewith taking into consideration the modifying influence of erosion, we must now consider one more factor, namely the time.

What we observe, however, is never a process of change, but only a condition at a certain instant; that is to say, a cross section through time. We imagine the process by placing together a number of such instantaneous photographs. One of the factors by which the picture is determined is the place which it occupies in the film: whether it belongs at the beginning, in the middle, or at the end. So with respect to the development of a certain weathering form, a manner of soil formation, it is necessary to state where a certain soil stands in time, that is in what stage it is in the weathering process. This leads to the differentiation of various stages of weathering, by which the different members of a series are distinguished by their external, their observable characteristics. Yet, on the other hand, these types are related since they are acted upon by one manner or type of weathering.

By analogy with the life of man, soil weathering can be differentiated into the following stages:

1. The beginning stage, the point of departure, the unweathered parent material.
2. The juvenile stage; the weathering has begun, but there is still much material unweathered.
3. The virile stage; the weathering is quite a bit farther along, but there is still yet present quite a good deal of unweathered material.
4. The senile stage; the weathering is for the greater part finished; while unweathered material occurs only sporadically.
5. The end stage; the development is completed; the soil is weathered out.

* * * * *

There are, of course, still many things to say about this, for example, with reference to the vegetation. **I** lasts but a very short time; very quickly a soil goes over into **2** and then the vegetation comes in. It is astonishing, how early a scarcely weathered soil can begin to carry even forest. In addition **2** is the time of great fruitfulness for natural vegetation, as well as for cultivation of crops. This also carries over into **3**. In **4**, however, the plants must get along on what the soil has been able to hold back through absorption; on what it has saved, one could say. In **5**, there is nothing left to wash out, thus also nothing more to be taken up by plant roots. The vegetation becomes poorer and poorer, practically fading away.

Later on further points will be mentioned.

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§5. A FEW MAIN KINDS OF SOILS

On the basis of the preceding sections it is conceivable, or theoretically

*See p. 113, footnote 73a.

possible, but not therefore necessarily desirable, to work out the relationships and to speak of all possible combinations of soil-forming factors.

We will now limit ourselves to a few main cases--cases which occur frequently and characteristically in the Netherlands Indies. I am confident that the reader himself, on the basis of the general statements made in the preceding sections can, according to the need, fill in the intermediary links.

* * * * *

As for the parent material, we will begin by considering the basic volcanic rocks which so frequently occur. Also, we will consider the basic volcanic ash and sand, which recently have been spread out during an ash rain and now form a thick homogeneous layer.

If we include all volcanic rocks together under the symbol **V**, and designate the **basic** ones by **b**, in contrast with **acid** by **a** and if we then differentiate still further, and indicate those finely ground up, with a large weathering surface, by **l**, in contrast to coarse and compact (rocks, massive lava streams, great boulders), which we will designate form **2**, then the parent material which we are here taking for our example is fully characterized by **V.b.l.**[108]

If we assume that the basic volcanic ash referred to has come down into the **H**ot low land (0-200 m. elevation) (**He**); and that the climate is continuously "wet," so that in the very porous material a continuously downward water movement (**NN**) takes place, and through which at the same time a continuous renewal of the air, **aeration**, indicated by the symbol **ae**, occurs in the soil, then the weathering conditions can be definitely specified by the formula **He.NN.ae**, and the question is now: to what does **V.b.l.--He.NN.ae** lead? and what are the stages **1** to **5**?

With the first shower that falls, leaching commences. The water at a temperature of about 25°C or higher, always falls without any solid material in solution and then dissolves and takes certain constituents downward. From the preceding discussion we know that first the bases calcium, sodium, potassium, and magnesium are removed, followed by silicic acid. FeO oxidizes to Fe_2O_3, MnO to MnO_2, these oxides remaining behind as the most difficultly soluble ones. Fe_2O_3, as well as Al_2O_3 remain as hydroxide gels, along with kaolin gel. Now these gels again absorb a part of the constituents dissolved in the water. The kaolin takes up the bases Mg, K, Na, and Ca, while P_2O_5 combines with Al, Fe or Ti.

Meanwhile vegetation begins to grow on the surface and a microflora very soon comes into existence in the surface soil. Besides plenty of warmth, moisture and light, originally a good supply of mineral plant nutrients is present so that the above-ground flora grows luxuriantly. The soil flora develops especially as a bacterial flora, since the pH is not far from 7 and the N cycle is at a minimum. Only the N fixing bacteria (whether in symbiosis with legumes or not) have the key to the situation. By this predominatingly bacterial flora the organic matter (the plant residue which falls from the above-ground flora) is to a great extent oxidized to carbonic acid, except for the small part which the microflora holds fast in their own organisms, and the small part that they scorn.

The water as it sinks downward and passes through the layers with the active microflora, takes into solution from those layers little else than much carbonic acid, which in its turn hydrolizes and leaches the glass and the minerals of the deeper-lying ash.

In this stage the condition has now become such that under the more and more developed forest a thin layer of plant residues (**O**) lies on the surface soil, which is the organic-material-holding soil horizon (**o**). Just below is the leached-out horizon (**E**) as above described. Together these layers (**oE**) can develop to 50 to 60 cm. thick, but frequently they are not more than 10 cm. thick. Beneath this is a layer (**E**) which does not have a sufficient

108. The first use of these symbols as applied to the Netherlands Indies, may be found in: Meded. Proefst. Java Suiker-Industrie, No. 16 (1931). See also footnote 70, page 112.

quantity of organic matter (in this case active bacteria, etc.), for it to be mentioned as such; this layer can be many meters thick. In the beginning this is obviously not the case, but the (**E**) horizon quite rapidly grades into the scarcely perceptibly attacked, fresh ash (**P**). Gradually, however, **E** gains over **P** and becomes more distinct and thicker.

If the weathering of the surface layer is already quite advanced, the profile itself has been developing a greater complexity. The silicic acid which at a pH of 7 to 6 is quite soluble (whether as the ion, or in the sol form), is the least soluble in a weakly alkaline medium produced particularly by solutions of Ca and Mg, thus with a pH of 7 to 7.5. As the water sinking into the soil (ash) goes down deeper, it continually takes up more bases as a result of which the reaction becomes gradually more alkaline, and at the same time the water becomes richer in salts. In this way somewhere in a deeper horizon a point is reached where SiO_2 must again precipitate. The result is a formation of tuff at that place. This develops into a layer, cutting off the percolating water, and thus making a water table above it. (See Frontispiece A.)

Just above the silicified tuff (an **I**-layer, although the German soil scientists would probably call it a "deposit" and indicate it by **C**) a portion of the profile becomes submerged and here the weathering is shifted from the **ae** to the **aq** form.

Meanwhile, with the further continued leaching of the **oE** and **E** horizons, the concentration of bases in the soil water gradually falls. The carbonic acid in the dissolved state which is carried downward with the water becomes more than sufficient to saturate these bases and convert them to the carbonate form. There is thus an excess of CO_2, and the pH sinks from above 7 down to 6 and perhaps yet still lower. However this does not diminish the leaching out of the SiO_2. On the contrary the reduction of the salt content facilitates SiO_2 washing out. But in addition something else also comes in: the kaolin commences to move as a sol and from this time on continues to move out.

Free Al_2O_3, however, is left behind as hydrargillite. Quartz also remains behind. And Fe_2O_3 too; but the hydrates of Fe_2O_3 begin to "age" and give up water. The color of the whole, first yellowish brown to brown, becomes brownish red and then red. The brown to brownish yellow soil (**E**), called "brown lixivium,"[109] becomes gradually "red lixivium." Upon the silicified tuff (**I**), over which the water flows away, in the **aq**-weathering (under water, without air) there occurs now a separation. The iron commences to move while the kaolin remains behind, and the iron deposits itself higher up, at the limit of the ground water. In this way there originate two layers, one above the other. The first is designated as I_2 of which by far the greatest part consists of kaolin. Upon this is I_3 consisting of iron oxide as a layer of ore. It is sharply layered, and in the dry state it may easily be rubbed fine. In the wet state it is not at all plastic, which is in marked contrast with the greenish or dirty white or light violet layer I_2.

Because I_2 is as good as impervious to water, and **E** is very pervious, as is I_3, the water level, due to the precipitation process, becomes gradually raised. I_3 is moved upwards and I_2 becomes thicker and thicker. Deeper down the iron oxide never exists as a solid; but above, where there is contact with the soil air it does, and I_2 originates through the active removal in the soil in the lowermost part of **E** where there is more air. This process can continue in this way until **E** is consumed and broken down into white clay I_2 with iron ore as I_3 upon it.

This layer I_3, however, always possesses a little kaolin, namely that which the iron oxide found in the place where it precipitated. If now, the kaolin from **E** is, to a great extent, washed out, the farther I_3 rises the smaller the admixture of kaolin will become. In other words, **E** itself does not always remain the same, but is gradually washed out and impoverished, first of bases, then of SiO_2, and after that, impoverished of kaolin.

And now what has happened to the Al_2O_3?--At the outset it is found uniformly distributed throughout the layer **E**, just as

109. Lixivium--a term referring to drastically weathered and leached inorganic residues.

was the Fe_2O_3. And just like the Fe_2O_3 it remained behind in **E** when all the other constituents gradually disappeared through leaching. But there beneath in I_2 the aluminum oxyhydrate also began to move, just as did the iron oxyhydrate, only somewhat more slowly. The result is the removal upwards, but later than the iron. The deposit I_3 must thus ultimately divide itself into a lower layer of Al_2O_3 in the form of hydrargillite, and on this lies the Fe_2O_3 layer in the form of different iron hydroxides.

Meanwhile a difference has also begun to develop in **O** and **oE**. **oE** is the horizon in which the organic life is, in which the roots of the plants seek their moisture and food materials, and in which the microflora lives and in a certain sense prepares those food materials. But thanks to the intensive leaching of **oE** and **E** there arrives a stage when the weatherable minerals, themselves, are finished and the absorbed bases plus P_2O_5, SO_4, etc., are also practically leached out. Then the vegetation moves in the cycle: **O** ⟶ **oE** ⟶ into the roots ⟶ into the plant above ground ⟶ plant residues ⟶ **O**, etc. But with each circuit losses occur, and the end must be that the vegetation becomes less and less and finally goes to rack and ruin. The microflora too, must continue in this way to autoconsumption and finally die. Then the pH of the water penetrating into the soil changes again from less than 6 back again to finally about 7. (In the colloid suspension, which has only a few H ions, the pH is of course considerably lower.) The layer **O** has meanwhile been consumed, and the layer **oE** changed back into **E**.

If there were no erosion, presumably the weathering would proceed in this way. But erosion does take place, and it alters the picture considerably. Already in the very beginning, the loose fresh ash washes off notably. However, as the vegetation develops more intensively upon the soil, the erosion becomes continually less and less. Under forest there is little erosion. But it is not entirely absent, for the water that runs along over the surface always takes something with it, and in the course of centuries the amount can be quite considerable. Moreover this washing off is of considerable influence, since it takes so much with it, especially from **O**, and in the material carried away is much plant food in more concentrated form than is found in **oE**. As the "senile" stage of the soil is reached and passed and the vegetation declines, erosion increases. As the pelting rains reach the bare ground, the erosion proceeds at an again increased speed to remove what there is still left of **E** (**O** and **oE**, have already practically all gone!).

In this way finally the layer I_3 becomes exposed: and the iron ore layer meanwhile hardened by loss of water and aging, becomes a "surface crust." Under this crust is found the accumulation of Al_2O_3 in the form of bauxite, earthy, but chiefly in nodules, and thereunder the more or less spotted white clay layer I_2, lying upon the silicified tuff, and this above the only slightly attacked ash.

In the Frontispiece (**A**) may be found the above-described profile development presented schematically, with time as the abscissa. All the stages which one runs across in nature should correspond with some vertical line in this scheme.

Whether this scheme as is given in the figure is entirely accurate, or whether all possible stages of it have been found, is, stated most mildly, yet uncertain. In a certain sense this is perhaps not so immediately important as the following:

* * * * *

There was once a time, when it was thought sufficient to characterize the "soil" of a place by taking some surface material from the uppermost layer, thus of the "ground," and on this sample to carry out an analysis in the laboratory. But since then further progress has been made in two directions.

In the first place, such analyses have been repeated for the same "soil" at different times, for example, before and after one or more harvests, and in this manner changes in the soil have been established and studied in relation to the time.

Secondly, freedom has been achieved from the idea that one single sample of the surface soil was sufficient to characterize

the soil as a whole. There is now a realization that the different horizons or layers which are found above and below each other belong together and that only the entire "soil profile" satisfactorily characterizes the soil. So it is that in all modern soil descriptions we always find sketches and statements describing the soil profile.

And now it is necessary to take the third step, which is already included in some soil descriptions, though it has not generally been recognized as an essential requirement of modern soil science. This requirement is: besides the description, to represent the continuous changes of the soil profile with time, from the beginning to the end. An example of this is the diagrammatic figure of the laterite soil (Frontispiece A).

This manner of representation offers all sorts of advantages. It permits making graphical the development of a profile, as well as its decay, and degradation. With one such figure, for example, "chernozem," and "degraded chernozem" can be presented together. If this doesn't succeed, then the latter is not to be conceived of as degraded chernozem, but must be regarded as a separate soil group.

Thus in the laterite profile drawing (Frontispiece A) we find several different types of Netherlands Indies Soils, i.e.

in stage **I**--fresh ash soils
" " **2**--so-called "tarapan"
" " **3**--brownish yellow lixivium, brown earth
" " **4**--red lixivium, red earth
" " **5**--"laterite"

and yet they really form one single whole.

If during the formation process there is added to the profile a new layer of ash from a volcano located nearby then, without difficulty this can be brought into the figure as a sudden surface addition. In the same way we can handle a covering over by a "lahar." If consequently there appear new phenomena in the older layers of the profile, then these can also be shown, for example, changes which the profile must undergo when, at some time, through geological or geomorphological causes, the terrain either sinks more and more under water, or through increased elevation becomes more and more dewatered.

Coming back to the formula from which we had started out in the above example, i.e. **V.b.I.--He.NN.ae**, it must also be stated that this formula is not equally applicable to all layers of the profile, but only for the uppermost ones: **O, oE,** and **E.** For practical purposes these are the principal and most important layers, at least in the first four weathering stages, as long as they still exist and are not eroded away. For as a matter of fact they carry the vegetation, which for mankind is always the most important question. But then it is also necessary to mention in the formula, the weathering stage, for example **V.b.I.--He.NN.ae.3.** This indicates that the third stage has been reached, and thus that we are referring to brown lixivium.

* * * * *

If we now leave the hot lowland and go toward the mountainous land of 2,000 m. elevation and more, then the temperature is moderate or temperate ("matig") and in the formula **He** is replaced by **Ma.** We still have the same parent material **V.b.I.** The rainfall is such that the soil is "continuously wet" (**NN**) and we select a place where the soil surface is convex, so that the water can both run off the soil and also penetrate through it, and the air always has access (**ae**). The formula of the soil formation then becomes: **V.b.I.--Ma.NN.ae(I-5).** And what is the result?

In the beginning of stage **I** the result very much resembles that of the preceding case; but if the vegetation develops into forest then something else happens. The temperature is no longer 25° to 30°C. but 13° to 18°C. In place of the bacteria, which at these lower temperatures are not nearly so active in the destruction of plant remains, molds come more into the foreground. These, as already stated on page 107, mineralize to a much less extent the organic matter. The consequence is that organic matter (**O**) accumulates to a certain depth and in spite of the leaching process, which occurs continuously, the soil layer **oE** is thicker

and richer in humus. However, because of the lower temperature, this last progresses differently and more slowly.

When the weathering process shifts over from the 1st to the 2nd stage, that is, when **O** and **oE** are quite clearly developed, then the soil water becomes altered. It is cooler than in the lowlands, and the water can hold more CO_2 in solution, and this lowers the pH still more. Moreover on the cool forest soil more moss begins to develop. This yields humus materials to the soil liquid, which also lowers the pH. Thus in **O** and **oE** the pH gradually falls below the values of 7 to 6 or 5.5 which are found in the low lands, and we find 5 or 4 and sometimes still lower values. Then, however, the hydrates of iron and aluminum oxides, originally precipitated in an insoluble state become movable, and, thanks to the protecting humus colloids originating from the surface soil **oE**, they move away together. Thus **oE** becomes bleached. In the beginning this is scarcely detected, but in lower horizons the deposited brown flecks and threads are easily seen, originating along wider passages where tree roots have died and disappeared, and also where considerable air can penetrate. And then, if horizons are reached which are not yet so extensively robbed of bases that the pH is still above 5 or even higher, the iron again precipitates as "ore" (**I**).

The chance that this movability of the iron may occur increases with the lowering of the temperature, and hence increases with the elevation. Below 2,000 meters, the phenomenon can be observed only sporadically, but more and more above 2,000 m. it occurs more frequently although far from everywhere. It is true that the pH must fall definitely below 4.5, and that is only the case 1st upon a parent material which inclines more from **V.b.** toward **V.a.**, and 2nd, under a vegetation such as produced by mosses and Vaccinums, which produce a strongly acid-reacting humus. In Central Europe is found an analogous condition. On the Veluwe, under oak and beech forest there is little or no shifting of the iron, while under Calluna and Erica, there is considerable. Thus under **O** there develops a grayish white layer **oE** to **E**, which is underlain by a brownish black layer **I**(ore). This is the true heath profile.

Repeatedly the question is raised whether or not "podzol" soils occur in the tropics. According to his description of the distribution of these soils over the earth, we come to the conclusion that Stremme[110] believes podzols are excluded from the tropics. Harrassowitz,[111] however, on the basis of the communications from P. W. E. Vageler records very positive podzol profiles from Palembang as well as other locations. It is however a question, whether in Palembang one is not dealing with more or less "drowned land" in connection with the great Post-Pliocene transgression of the sea. At that time much red earth was lowered into subaquatic or at least amphibian conditions, and it is obvious that then occurred a bleaching by humous water, with an extensive formation of iron concretions under it. Humus-rich ore is of course not recorded, since with the high temperature of Lower Palembang the deposit of this ore must a priori be excluded.

If one would find true podzol in the tropics, he must go into the cold regions, thus up into the mountains.[112] Also, the soil material must be suitable for it. On Java, for example, the parent material is very different from that of Central Europe with its extensive plains or undulating land of allochthonous material, rich in quartz sand. Stremme records a series of podzol profiles, but only upon sand, sandstone, granite sand, loam, or schists; not a single podzol upon basic, volcanic material. Judging according to these examples, in the Netherlands Indies one should thus search especially on the high lying quartz schists, old slates, and sandstone, thus in the high lands of Atjeh, Central Borneo, and New Guinea. And in the 3rd place the vegetation must be

110. H. Stremme, Die Verbreitung der Bleicherde, Wald-u. Heideböden., Handbuch der Bodenlehre III, (1930), p. 158-160.

111. H. Harrassowitz, Böden der tropischen Regionen, Handbuch der Bodenlehre III (1930), p. 371.

112. Cf. E. C. Mohr, Jul. Tropical soil forming processes with particular reference to Java and Sumatra (translated by Robert L. Pendleton), (Peiping, China, 1933), pp. 21-22, and 38.

exactly suited to it. Upon New Guinea above 3,000 m. presumably there exists the best chance. But thus far no podzols have been found there.

However, it will be some little time before any one will study in the high altitudes of New Guinea the flora in its relation to the pH of the soil. Vageler[113] thought that under definite plants he was able to establish the existence of miniature podzol profiles. Apparently notably different pH conditions can prevail in a definite soil type within short distances.[114]

Through this the attention is once again fixed upon the fact that the soil in nature is something different from earth in a bottle, which is studied in the laboratory. If, in spite of that, the pH for example, is determined on the soil in the laboratory, one takes an average sample and so determines an average pH in, say, 200 grams of soil. If one then finds a value of 5, then in the original soil from which the sample was taken at a certain point, even in 1 $cm.^3$, a pH of 5 can occur, but at another point the pH is perhaps above 6, and at still another point 4 or even lower. Thus it is conceivable, and even likely, that in a soil, even in a definite layer or horizon with an analytically determined pH of 5, no iron hydroxide comes into movement, but it may occur within some definite cubic centimeter or even cubic millimeter. If the acid soil liquid with iron in solution or in the sol form, goes into such an environment that the pH again must fall, then the iron again precipitates. This is what causes the "spottedness" in such layers which form the transition between areas where nothing happens to the iron, and layers where all the iron is subjected to solution and transportation.

This may explain why when there are thick E layers with much iron deeper down, they almost always are spotted. The British call these layers "mottled clay."

As long as an E layer possesses much colloidal iron oxyhydrate in an undispersed state it is of a loose consistency (structure). It does not stick, it is not plastic, and it is pervious to water and light. If, however, the iron oxide becomes leached out and iron-free kaolin (this last word is again used in a broad sense, so as to include kaolinite and other similar minerals) remains, then the consistency becomes sticky, plastic, tough and impervious. If then the iron (originally perhaps 10% or more of the dry soil) has entirely gone, or has collected together in hard concretions of brown iron ore, so that per cubic meter there is still approximately just as much Fe_2O_3 present as before, yet it is of no importance. The kaolin-like mass lying in between has, as just now pointed out, the characteristics of "fat clay." The stage "mottled clay" = spotted clay, is thus just an intermediate stage. All the iron has been removed from it. The end product of the process going on is white clay possessing at most a few coarse iron concretions which, since they are so coarse and smooth and sometimes crystalline that they resist solution the longest. In these cases the color of such concretions varies from yellow to yellowish brown and also toward brownish black.[115]

Sometimes, especially in the lower mountainous country, one comes upon "mottled clay" as practically the surface soil layer. This is then to be considered to be the I_2 horizon in the development of that soil, but as a result of premature heavy erosion, for example after deforestation, it was exposed at the surface before a distinct iron oxide crust, which later would be called a "laterite" crust, had formed on it. (See Fig. 22, page 149).

On the basis of what already had been said on the subject of V.b.I.--Ma.NN.ae. the profile may now be characterized

113. See under Harrassowitz, l. c., p. 371.

114. Hardon has since reported podzols from New Guinea (H. J. Hardon, Podsol profiles in the tropics, Natuurk. Tijdschrift. le Afl. van Deel, XCVI). I have found ground water podzols developed in the sands of the ridges formed as barrier beaches along the coast near Pattani, southern Thailand (Siam). --Translator.

115. Cf: E. C. J. Mohr, Over ijzerconcr. en lateriet in Ned.-Indië, Verh. Geol. Mijnb. Gen., Geol. Serie, Dl. III (1916), p. 133-148.

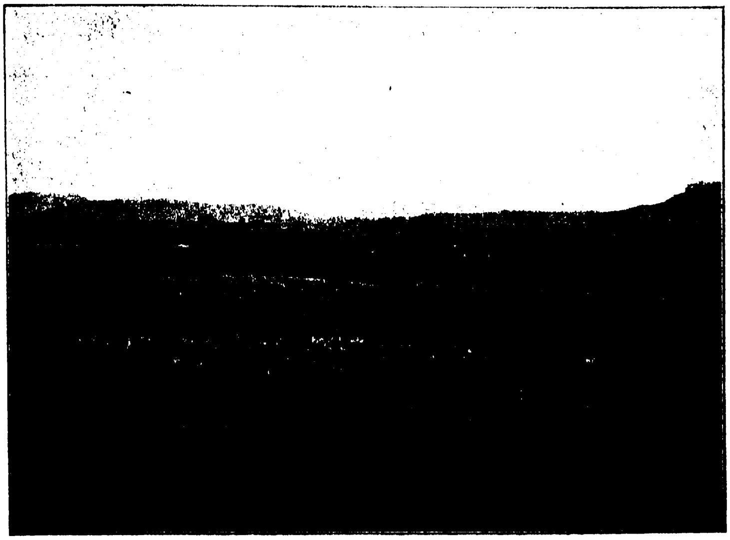

Photo by Mohr

Fig. 22. West Flores—To the north of Roeteng. Poor country due to the "mottled clay" and laterite exposed by erosion.

Photo by Mohr

Fig. 23. Northern Sumatra. Redelong.—Profile in a road cut on the southeast slope of Boer ni Geureudong. 1300 m. elevation. **O** about 5 cm., **oE** about 40 cm., **E** undetermined. Previously a lahar: **V. (a + b). (I + 2)--Ma.NN.ae.3.** The large andesitic rocks can easily be completely determined, yet can be cut through with one blow of a heavy hoe.

as follows:

The higher the elevation one reaches in the tropics, the cooler it becomes, and always in the forest the more will the layer **O** be apparent, as also the humous layer **oE**. The latter will retain the brownish yellow and brown tints longer than the corresponding **oE** horizons in the lowland, for in the mountains drought is less frequent and less severe and the temperature is lower. Moreover in the more rough mountainous terrain there is, as a rule, more erosion, with the consequence that much brown soil is washed off before it has yet had time to become red as a result of aging. At 2,000 m. and higher in the Netherlands Indies I have never seen red earth which might be supposed to have developed according to the manner of weathering described here. Even if one goes somewhat lower, for example to about 1,500 m., only seldom can red soil be found, and then it is still doubtful whether the origin was the same as the one which is here meant.

When in Java, for example, at this height we find red earth, then in many cases it can be shown that we are dealing with a terrain which has been raised up to this elevation through tectonic movement, for example a region of Tertiary age such as limestone or marine tuffs. These formations, then, after their elevation out of the sea, originally weathered at sea level or a little above, so that their brown had already changed into red, and thereafter or in the meantime were farther raised up. In a certain sense then such red soils above 1,500 or 2,000 m. might be called "fossil redearths."

Another possibility is that in the mountains a layer of brown eluvium or lixivium may have become covered by a thick layer of fresh, hot volcanic ash. Then without doubt that brown layer could become "baked" to red earth. If later the new ash again erodes off, the "redearth" is exposed and gives the false appearance of having become red by weathering in place.

Coming back to the brown earth of the mountainous land, the brown lixivium, a characteristic property of it can now be recorded: Above 1,500 m., or even a couple of hundred meters lower, it exhibits a peculiar structural difference, which in the Netherlands Indies is called "mountain granulation." In this granulation out of finer material there form gains 0.05 to 2 mm. in size, and sometimes still larger. These "crumb structures" differ from the ordinary crumbs which generally occur in the low lands and which again easily disperse, for example simply by becoming beaten apart by a heavy rain. The "mountain granulation" grains remain intact, on which account they have been given the name of "pseudo sand" or "false sand." Microscopically they appear to consist not only of fine mineral powder of original minerals of the parent material, but also of weathering minerals such as opal, chalcedony, kaolin-like minerals, and iron oxyhydrate in different forms. The binding material, which cements this fine powder into the so-called grains, is still inadequately defined. Classifying it according to the color, it quite probably contains iron oxyhydrate. It seems plausible to suppose that the very local depression of the pH to below 4.5, as described upon page 148, (for example, through microbiological activities taking place within a definite cubic millimeter), so that iron oxyhydrate can become movable, can cause the formation of the "pseudo-sand." However there is yet no experimental proof in this direction. Only that it is established that the phenomenon generally occurs everywhere in the mountainous regions of the Netherlands Indies. In Java in some cases it occurs at as low as 1,000 m. elevation, while in Sumatra at certain points, even still lower.[116]

The consequence is that the surface soil behaves in some respects as a sandy soil. It is very pervious, well aerated, but at the same time on slopes it is very much subject to sheet erosion by rain water, and in times of drought to the

116. This mountain granulation I have also observed on the higher mountains in the Philippines, at elevations above about 1000 meters. On Mt. Katanglad, Mindanao the light yellowish brown clay soil from the moist forest is so well granulated that it is even looser than sand, and having a lower specific gravity than sand, feels more like sawdust. Yet when puddled this soil is at once recognized as a clay. --Translator.

so-called "dry wash" (see pages 140-41). Biologically and chemically, however, such soils re much richer than many sandy soils of the lowlands, especially much richer than sandy soils high in quartz sand. For it is true that the "pseudo-sand" consists to a great extent of colloidal constituents. This is also evident from the publications of Deuss[117] who shows that a number of such mountain lixivium soils are among the best tea soils. More about this later.

* * * * *

Now if we turn toward those regions of the Netherlands Indies where the wet monsoon alternates with a distinct dry monsoon; thus passing from the tracts indicated by blue on the map (see Fig. 6) to those shown by yellowish green to red. In these tracts then (again with the same parent material) a continuous water movement (**NN**) down through **V.b.I.**, cannot take place, instead **NN** changes to **Nr**. Now to what does this lead: **V.b.I.--He.Nr.ae**?--In the wet season the same things happen as with **He.NN**, but not in the dry season. In this latter period there is a drying out, a rest period. This intermittent weathering leads to a similar result as does the continuous washing or leaching, only more slowly. Small differences may however be noticed.

The annual substantial drying out of the surface layer compels the vegetation of **He.Nr** to be different from that of **He.NN**. The stronger the dry season it has to endure the more the deciduous forest comes into the foreground. This means that during several months of the year no organic matter is produced, while upon and in the soil the consumption of organic matter still goes on, although in the dry season it is to a lessened degree. The result is then that under **He.Nr** less organic matter is found in the soil. The opportunity for movement of the sesquioxides is also smaller. The pH approaches 7.

A figure similar to Fig. A (Frontispiece) would appear somewhat different. In the first place the time would be somewhat longer, thus the length from left to right somewhat greater and more linear. Then **O** and also **E** would be less developed. The **E** horizon due to the more thoroughgoing drought will move from yellowish brown toward reddish brown and toward red. In Java this is to be seen very clearly in the regions with a pronounced dry period (see the small map, Fig. 6). Here we see this reddish brown tint appear in weathering stage **2**. This is a phenomenon which in many wetter regions can be observed only later in stages **3** to **4**. As to the erosion, though that caused by rain may finally be just as heavy, we may say that this is less in proportion as the number of heavy showers per year decreases. On the contrary the "dry wash" increases with the dryness, just as does the wind erosion through simply blowing the soil away, when the hot dry monsoon wind takes up the red dust, which has been developed through slaking down along millions of hair-like cracks. This dust is deposited in windless valleys and other moist spots where, once it has again become wet or moist, it remains. In the same way just as with **He.NN.ae** a complex of alluvial layers I_2 and I_3 is formed under **E**, in rare cases also under **He.Nr.ae**, which is later removed exposing the I_2 and I_3, and then again we have a case of the laterite "crust" exposed at the surface.

This laterite crust may be somewhat more solid and harder than under **He.NN.ae**. Because in the last stage of **He.Nr.ae**, when still only a few dm. of **E** remain, in the dry monsoon ascending water can approach so close to the upper surface that evaporation can alter the character of the weathering into **He.NS.ae**. This means that what is dissolved in the water becomes deposited in the surface layer, finally in the porous but hard layer of iron oxyhydrate I_3, called "laterite in the narrower sense." Beside traces of such bases as Ca, Mg, K, and Na, these dissolved materials referred to possibly include iron and aluminum oxyhydrates, be it then in a very dilute state.

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117. J. J. B. Deuss, Over de theegr. van Java en Sumatra, Meded. Proefst. Thee, 55 (1917) and 89 (1924): Bergcult., I (1926), p. 133.

In the literature which has appeared in the last few years relating to the formation of red earth and laterite,[118] it has been rather generally accepted that the "laterite in the narrower sense," that is, the laterite crusts, can only "develop on the surface of the soil in climates with a strong dry season, since then the water can rise to the surface, and as the result of the evaporation of the water dissolved Fe_2O_3 and Al_2O_3 can precipitate there." These are the conditions I have described above as an **NS** movement of the water.

According to this reasoning laterite would be excluded from the surface where there is an **NN** water movement, although according to the considerations developed on pages 144-145, it is entirely possible. And experience also gives examples of laterite "crusts" on the surface in regions where the dry season is of slight or no significance, and no ascent of water need be taken into account.

Further, we saw a moment ago that with a thick **E** layer and pervious soil there is no possibility that water can ascend to the surface layers. Thus laterite formation would also be excluded until the last or the next to the last stage (see above).

The ascent of ground water does play an important role in the type of weathering which at the beginning is indicated by the symbol **NS**. As explained on pages 64-65 this kind of weathering can occur only if the parent material, **V.b.I.** is exposed to weathering in a layer not thicker than about 1 m. above the ground water. For only then is ground water drawn up into horizons from which it can evaporate. But as will appear further (page 154) in such cases generally no "laterite crust," is formed not even any red earth at all.

Consequently, according to our insight, disappointingly little remains of Harrassowitz' hypothesis, which is at present so generally accepted.

In so far as our knowledge goes at this moment, it cannot be understood how a crust of iron oxyhydrate containing aluminum oxyhydrate could possibly form on the surface of the soil.

In cases where the soil moisture alternately sinks and rises, **NS**, the sinking water must take with it the last traces of bases as well as silicic acid, both as ions, or as a sol. Would the reversed, ascending water leave behind it these constituents and in place of them take back up the sesquioxides? How could that be? By the help of protective organic colloids? But do not these come from above rather than from below? If they are of assistance they will do just the reverse of what the hypothesis calls for, that is, they will assist in moving the sesquioxides downward. Moreover, if the bases and even SiO_2, (thus also kaolin), are nearly exhausted, the vegetation on the soil will no longer be worth much. And so, from where will the protective colloids come? This attempt at an explanation obviously does not get us very far!

In cases of continuous or intermittent descent of the soil moisture, **NN** or **Nr**, at last we have a final chemical composition similar to that of the laterite crust, though crusts do not result. What influences the red earth to develop a crust in the final stage? Thus far there is no indication as to why, although a priori it is not inconceivable that, through an agency unknown thus far, Fe_2O_3 in a very pure hydrate form may become cemented together, crystallized, via an intermediate stage of solution.

* * * * *

Since both occur fairly often in the Netherlands Indies, two of the factors modifying the profile now need brief consideration:

First, the breaking of the white clay layer **I₂** and the (silicified) tuff **I**. As to how that may happen, through earthquakes or landslides, or whatever it may be, need not here concern us. The main

118. **This is not the place to deal fully with the very extensive literature. In the Handbuch der Bodenlehre III (1930), p. 362-436, Harrassowitz has done that. It must here suffice to criticize these conclusions, and to discuss what has subsequently been published, in so far as it contains new points of view.**

point is that water moving downward penetrates into the tuff. Perhaps it is not always necessary to have an accident for this to happen. The water, once it is impoverished of bases and of free silicic acid, can slowly flow down through the clay layer to the underlying tuff until it finally reaches the ash layer which is still unweathered. But, when once the water has penetrated into the ash layer then through leaching there begins a weathering of **P** toward **E**, precisely as if the tuff and the fresh ash lay just under the layer **oE**, or at least continuous with the uppermost part of **E**. There develops a new E layer and the percolating water seeping downward moves through to where again as a result of a deposit of SiO_2 there is an inducement for formation of a new tuff, cutting-off layer I_1. Then water collects above this layer or flows slowly, with the consequence of the formation of a new horizon I_2, a gray to light violet clay, with above it horizon I_3, a precipitation of iron oxyhydrate plus aluminum hydroxide.

Theoretically, this sort of phenomenon can repeat itself many times, for example in connection with a secular deeper cutting down of rivers. But before this has gone so far, usually other geological events interrupt the regular development. Sometimes the results of such a process are clearly discernable, as I have seen a few times in profiles of 50 m. or more in deep ravines which are like deeply cut river valleys. Here at distances of 5 to 10 m. are exposed similar double horizons of white clay, I_2, with iron ore or iron ocre, I_3 above them in what appeared to the eye as a very uniform, brownish red **E** mass of great thickness. While geologically, as calculated from the eruption which was the cause of the deposit, the material might all be of exactly the same age. The mass, however, was composed of diverse **E** layers of different pedologic ages.

And then also the following: If a repeated profile as described here, is eroded from above, the time finally comes when the uppermost layer of ore appears on the surface as a laterite "crust." (See Fig. 24 where several I_3 layers are exposed.) From the nature of the case the clay layer lying below is no longer entire, otherwise the water could not have gone through it and given occasion for the development of the deeper **E** layers, etc. Apparently the descending water from the

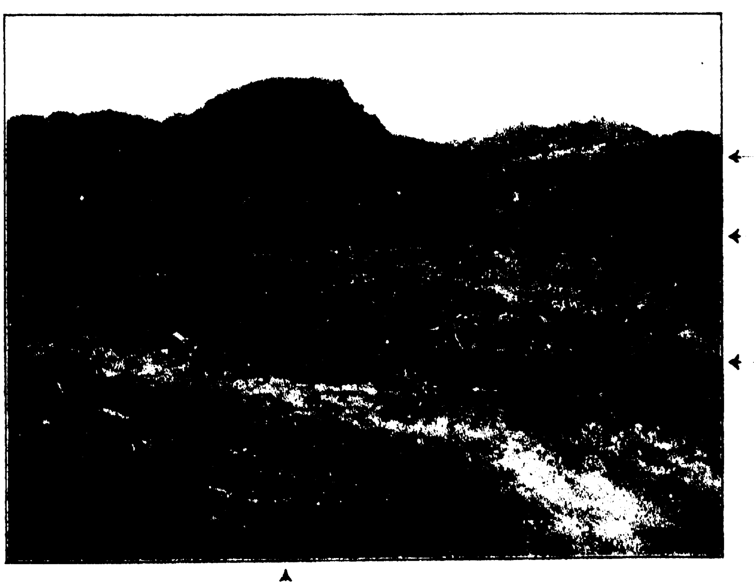

Photo by Mohr

Fig. 24. Central Java, west from Pati, south slope of the G. Patiajam, near Ngrangit. The layers of laterite (iron concretionary hardpan)--V.a. I/2--He.3/4 exposed by erosion giving the impression of superficial formations.

clay layer takes considerable material toward lower horizons. Hence if the laterite crust is broken through and under it there is found a brownish red **E** layer of red earth, it is entirely understandable if the following conclusion be drawn. This concretionary laterite crust on the upper surface has originated from **E**, thus the iron must have ascended up from it. While this is certainly conceivable it is by no means the only possible explanation.

* * * * *

The other modifying factor above referred to is when new deposits, such as fresh volcanic ash, **V.b.I.** are laid down on top of **E** and **oE**. When for example the ash is very finely divided, a new ash layer of this kind may be of a similar slight porosity as the underlying soil. But it may also be coarser, sandier and hence much more pervious.

In the first case, in the beginning the water penetrates unhindered. But because of the alkaline reaction of the sinking water (it having passed through the fresh ash) the horizon **E**, at least in the uppermost portion, will tend to disperse and will consequently run together ("verschlämmen"). This is especially true if that ash-extract possesses much Na. If in this way a difference in permeability develops, then water accumulates at the boundary, in the lowest, quite pervious ash layer with the consequence that there is an opportunity for differentiation into a bleached clay layer overlaid by a layer of iron oxyhydrate.

In the second case, the water level originates in the fresh volcanic sand below, and there is also the above-mentioned differentiation. In this case it is still more easy to understand that the ferrohydroxide which is liberated from the darker minerals must precipitate as ferrihydroxide on the upper edge of the drowned layers, where water containing oxygen can come in contact with it.

In both cases, while the higher-lying ash weathers to **E** with **oE** on top of it, there forms just above the original separating plane a double layer, $I_2 + I_3$, of the same sort as the one described above. And also this phenomenon can, by successive ash coverings, occur several times, so that a repeated profile as sketched above, can also originate in this manner. A satisfactory differentiation between them is possible only as long as one can tell by the unweathered minerals in the stages (**1**) to (**2**), whether the layers between the double layers I_2 and I_3, from above downwards, become older, or the reverse.

* * * * *

After discussion of the continuous (**NN**) and the intermittent (**Nr**) leaching there now follows a more detailed consideration of the alternating weathering (**NS**).

The occurrence of this type of weathering is limited by the nature of the case. It can occur only when the ground water has a certain position. If that level be too low, then the weathering becomes **Nr**, since in the dry season the water cannot get back to the surface again. If the level be too high, then the soil is saturated, or "under water," so that weathering with air (**ae**) is replaced by weathering without air (**aq**). For a quite pervious soil material the ground water must stand at between 0.5 and 1.5 meter below the surface, and it must maintain about this level.

In order to have a marked ascent in the dry season, (the **S** of the formula), we must suppose a quite distinct dry season, and also a luxuriant vegetation. In the rainy season the leaching process will take place with the downward transportation of bases and silicic acid which move out laterally. The sesquioxides remain in place undissolved. This is all just as with **NN** and **Nr**. In the dry season, this solution reverses its direction of movement but with much dissolved bases, carbonate and silicic acid-containing water, and with a pH which will lie above 7. Again there is no opportunity for the replacement of sesquioxides. At most the water which ascends can bring with it a little ferrous carbonate, from which a little ferrihydroxide may segregate in the well-aerated surface soil (as ore, but also as small concretions).

But the possibility exists that

the soil moisture, which has an alkaline reaction, will during ascent become more concentrated by evaporation. Then it will alter certain organic substances (for example, tannin and its derivatives) through oxidation (and reduction) into intensely dark colored, even black compounds. Hence if a fresh ash **V.b.I.** is exposed to weathering under these conditions, as soon as vegetation once gets started upon it, the resulting soil is not brown nor red colored, but black, since the intense black color entirely obscures the brown and red of the iron oxide. In the beginning however, this "black" is still rather gray. (See Figs. 25 and 26, page 156.)

The material that gives the black color to this (and many another) soil type is peculiar. Up to the present time its chemical nature remains unexplained. Upon treatment with alkaline liquids, which dissolve the so-called "true humus matter" with dark brown color, this black color is practically not affected at all, nor is it soluble in acid. Microscopically it occurs as minute coalblack grains, of about 0.001 mm., (1 mμ) diameter. Thus it is not highly dispersed and one can hardly class it with the active colloids. There is, however, some uncertainty regarding this point, for there have yet been far too few investigations carried out along this line.

If we now inquire about the course of the different stages of the weathering: **V.b.I.--He.NS.ae**, it is difficult to give an answer. On several sides this weathering form is enclosed by others, and in the course of time gradually goes over into one or the other different forms. If the soil water which has reversed its direction also contains silicic acid, it can lead to the gradual formation of tuff. The soil becomes difficultly permeable, and the final result is something different. Also, the ascent of sodium with the water makes the soil less permeable, not by the formation of tuff, but through an alteration of the structure ("verschlämmung"). If, on the contrary, the ground water sinks, then there is likely to be a transition over toward **Nr**. Thus brown lixivium is formed which later becomes red **E**, under a layer **oE** which, due to the presence of the above-described fine black dust, appears very humous, but may perhaps be anything else but that. This is a soil type which Vageler so accurately characterized by using the expression "Blender" (blinded). But here we are already getting over into the sphere of agricultural evaluation.

* * * * *

In the cooler (mountainous) regions of the Netherlands Indies the **Ma.Nr.ae** and **Ma.Ns.ae** kinds of weathering do not occur. At these high elevations, because of the rains from the ascending air currents, there is seldom or never an intensive dry period. One might mention certain exceptions such as the Idjen plateau. For that matter that plateau does not lie high enough, only 900-1,400 m., and it is well drained, so that, for example, in stage **3** under a distinct humous layer **oE**, one finds yellowish brown to reddish brown lixivium **E**. But a majority of the soils are still in the more juvenile stages **1** and **2**, and have more of a grayish color.

In the higher mountainous regions the stages **4** and **5** do not occur. It is obvious that this is no accident, but stands to reason, and for the two following reasons:

(1) The topography there is much rougher, sometimes very much more so. This obviously very greatly promotes erosion from the surface. And at the lower temperature weathering progresses much more slowly. Consequently erosion keeps up with weathering and the formation of the further developed stages. Therefore, before stages **4** and **5** can be reached the surface material is all gone, and again deeper portions of the material, having now become surface soils, are subjected to weathering.

(2) Here volcanoes have to be considered. The longer the time that passes, the more chance that a new covering of ash will rejuvenate the soil. Hence, in the higher mountainous regions the stages of soil development oscillate between stages **1** and **3**.

* * * * *

Photo by Mohr

Fig. 25. East Java, saddle between the Idjen Mts. and Mt. Baloeran. Park landscape, with among others Acacia leucophloea. Black dust soil with gravel: V.(1 + 2) -- He.Nr.ae.2 to He.nvv.ae.2.

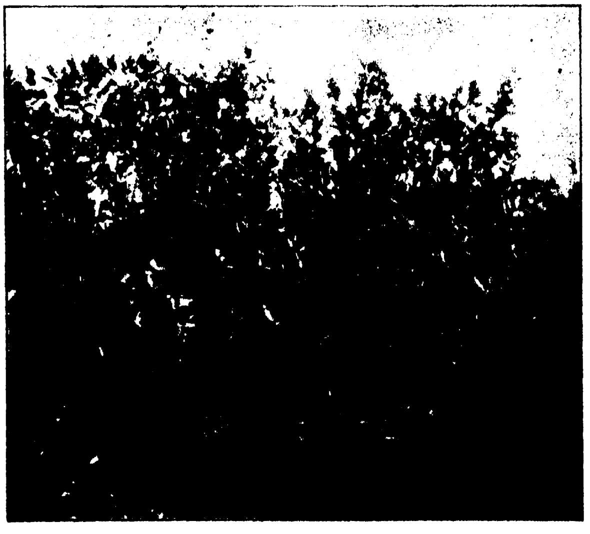

Photo by Mohr

Fig. 26. Flores, just south from Maoemere. Black dust soil with gravel: V.(1 + 2) -- He.NS.ae.1/2. Vegetation: vidoeri (Calotopis).

Let us now consider what happens to **V.b.I** if the ash comes to rest under water. Thus if in the formula, **ae** is replaced by **aq**. How does the volcanic ash weather subhydrically or subaqueously (for, example, in a fresh water swamp (rawah))?

V.b.I.--He.NN.aq(I-5) is then the formula.--The climate is warm. There is no dry season; the water standing on and in the soil becomes continuously diluted by rain water, and the surplus runs off over the surface, some of it also percolates down through the soil. The bases are of course washed out. The original reaction of the soil was definitely alkaline, but becomes more and more acid as vegetation develops on the soil. This increase in acidity is, on the one hand, due to the loss of the bases, and on the other to the fall and accumulation of plant remains, which under water cover the soil and if attacked by anaerobic bacteria, produce more and more organic acids and acid-reacting organic colloids. Already in stage **2**, the water becomes brown colored, while the color is stronger in stages **3** and onward. The pH, which in the commencement in the soil is perhaps 7.5, sinks to 6, or to 5 and even lower. As 4.5 is reached, the sesquioxides become movable, and are washed out, either as sols, protected against precipitation by the organic colloids, or as ions.

The soil thus becomes bleached. Even the larger, iron-containing crystals such as flakes of mica, become bleached and colorless. But some organic material remains behind. On the surface of the soil is a black layer **O**, and under this a gray layer **oE**, for the most part gradually grading into the white layer **E**.

In quiet water under a swamp forest the layer **O** can attain considerable thickness, and then becomes peat. More about that presently.--However under or in flowing water, this organic layer becomes of less significance; especially if the water flowing to the place is originally river water which contains bases, especially calcium. For then the pH cannot fall low enough (not below 4.5) to prevent the organic matter being attacked by microorganisms.

For: organic acids (pH $<$ 4) + $Ca(HCO_3)_2$
$\longrightarrow$ Ca salts + H_2O + CO_2(pH $>$ 4.85)

Or expressed in words: the lime combines with the acids which inhibit the microorganisms in their development, leaving in the place of the acid Ca salts or absorptive Ca compounds which can serve as food substances for the microflora. Carbonic acid permits a pH no lower than 4.85, for at that concentration the excess goes out of the saturated solution and into the air, as gas. (See Fig. 27, page 158.) The less the quantity of bases, however, which occur in the water flowing in, the greater the opportunity for a much lower pH and of a residue of organic matter remaining over, since the consumption cannot keep up with the production.

As long as the water in the surface soil and that standing above it still possess adequate inorganic nutrient salts as well as N compounds (ammonia) to maintain an active anaerobic bacterial flora, then all the plant remains from above coming directly into the water are converted into a formless, black mass, a sort of peat stew, which while somewhat like "low peat" of the cooler zones of the earth, is yet more completely broken up, ("vermodert"). The pH is quite high.

As these salts wash out and as at the same time the pH decreases, the living conditions for the above-mentioned microflora become less favorable. The activity of the microflora decreases and there gradually accumulate more unaltered remains of the plant residues. The intense black changes into a dark brown and later into a lighter brown. From beneath upwards the peat acquires more and more the character of the European "high peat," in which roots and branches are clearly recognized. The pH is then gradually depressed from 7 or above to 4 and 3 and sometimes still lower. (See Fig. 28, page 158.) Let us now look again at the soil layers under the peat.

The layer **oE** is to be conceived of as **E** with an infiltration of all sorts of things from **O**. According to the British Indian investigations already above referred to[119] a peculiar microflora lives in **oE** as

119. See pages 68-69.

Photo by Mohr

Fig. 27. West coast of South Celebes. Near Pangkadjene.--A wave-cut terrace at the foot of the limestone mountains. Soil only 1 foot deep: **(K + V) --He.Kr.am.3.** Bleached soil flecked with rust, containing many bog ore concretions. No peat on the lime.

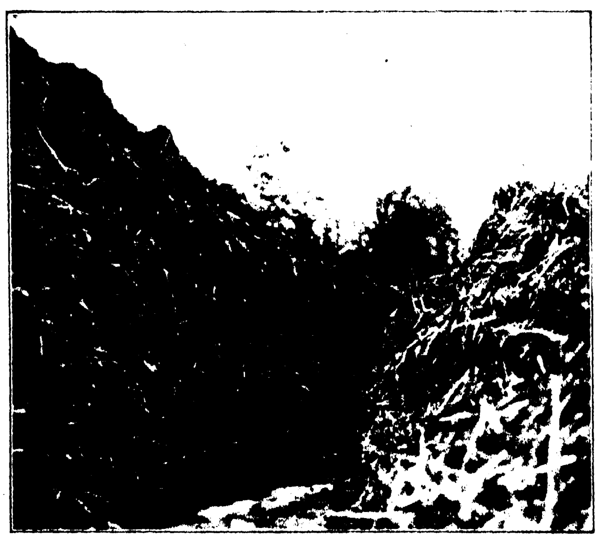

Photo by Jhr. F. C. van Heurn

Fig. 28. Sumatra's East Coast.--Close to Laboeanbilik, a drainage canal through thick layers of peat, pH of the water seeping out about 3 to 4. Color of the peat that of "loose turf," brown.

PROGRESS OF THE WEATHERING V.b.I.--He. NN. aq (1--4)

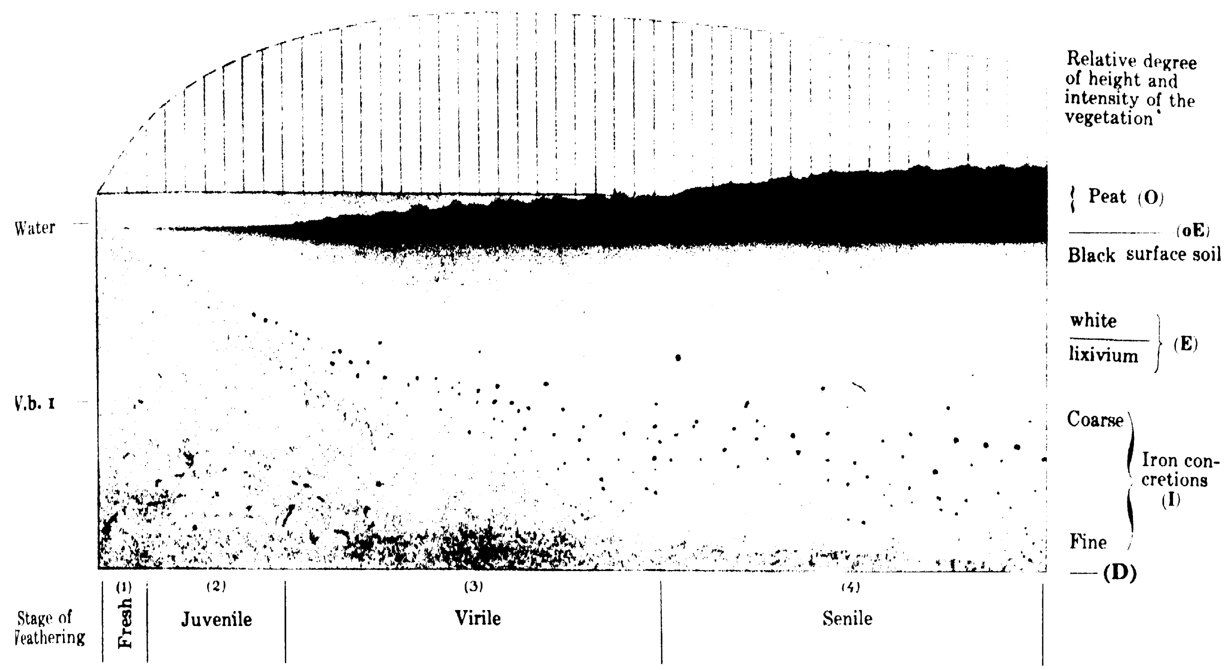

Fig. 29. Progress of the weathering V.b.I.--He.NN.aq(I-4).

long as adequate food materials and the pH permit it. This microflora under the anaerobic conditions prevailing there produces, besides CO_2, also CH_4 and H_2. The greater part of the iron will certainly become reduced to the ferrous state (-bicarbonate), but that need not occur quantitatively in the liquid which seeps through the soil. Ferrihydroxide, in the sol form is present in the soil solution. From borings[120] it appears that ferrous carbonate or sphaerosiderite can separate from such water in deeper, younger layers. This is presumably so because Fe^{++} ions dissolve out of the unweathered minerals in the parent material containing Fe^{++}, which with the $Fe(HCO_3)_2$ produces the precipitate of ferrocarbonate. Between these, Fe_2O_3 concretions as "hail ore" are found in the drill core. This iron has then precipitated bcause the pH of the gravitational water is gradually increased as it goes downward. It may increase from less than 4.5 to 7 and higher due to its passing through juvenile material which can still yield bases.

If the swamp vegetation has developed rapidly, then the occurrence of these hard, round, dark brown iron concretions can be observed in a relatively young E layer at a depth of less than 1 meter. But with the progress of the leaching out of bases from above the horizon of formation of these concretions also shifts in the same direction and the highest lying concretions once again come into a condition where they can be dissolved and can disappear. The horizon of the iron concretions is thus the boundary between the senile E layer and the still more or less juvenile D layer. These various points are schematically represented in Figure 29 above.

Concerning the E layer, and also the oE layer, it may now be stated that as they become more acid, less and less silicic acid goes into or remains in solution, also kaolin goes over less and less into the sol state, and hence is not readily washed out. Consequently, as the stages 3, 4 and 5 are reached, E approaches the composition of kaolin plus silicic acid. If from the

120. See Rpt. van D. Drost aan den Gemeenteraad van Batavia, I Juni 1916.

parent material there by quartz present, then it sometimes grows quite perceptibly. Upon further investigation one comes across opal precipitations, the latter sometimes changing into chalcedony.

Given that quartz and chalcedony exhibit practically no loss on ignition, while on the contrary kaolin (crystallized as kaolinite flakes: $Al_2O_3:2SiO_2:2H_2O$,) shows 13.94%, it must be possible with such a simple composition to figure out from the determination of the loss on ignition of such a white final soil **E** = **He.NN.aq.5**, how much quartz and how much kaolin are in it. While this has not been done for volcanic ash, it has been by C. P. Mom[121] for granitic material from Banka (Table 53):

only a separation into fractions according to grain size, but at the same time a separation into mineral components of the soil, and this latter is frequently much more important than the former.

If after this digression into a granitic terrain, we turn again to the parent material **V.b.I.** it is obvious that no primary quartz is present. At most it forms secondary chalcedony in the kaolin and from that some quartz in the course of a long time. The kaolin may thus be rather pure, though it is sometimes also rich in accessory silicic acid. In other cases the content of Al_2O_3 is quite high and thus the product is apparently more like allophane.

* * * * *

Table 53

Sample Number	Determination by analysis			Total of	Ratio mol.	Calculated from II		Quartz Calculated from III-VII %	Kaolin Calculated from II and VI and VII %	Total of VIII and IX %	Mechanical analysis		
	Loss on Ignition % H_2O	Al_2O_3 %	SiO_2 %	columns I, II, III %	H_2O to 1 mol. Al_2O_3	H_2O in Kaolin %	SiO_2 in Kaolin %				Sand > 50 mu.	Silt 50-5 mu.	Lutum < 5 mu.
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
4987	5.1	15.0	78.8	98.9	1.93	5.3	17.6	61.2	37.9	99.1	66%	7%	27%
4988	8.5	24.0	67.1	99.6	2.01	8.5	28.2	38.9	60.7	99.6	38	18	44
4989	11.5	32.2	55.4	99.1	2.02	11.4	37.8	17.6	81.4	99.0	23	10	67
4990	7.8	20.9	71.8	100.5	2.12	7.4	24.6	47.2	52.9	100.1	35	11	54

The close agreement of columns I and VI strikes one at once. Column IV shows that there can be present but few other minerals than kaolin and quartz. Column V shows that for 1 mol Al_2O_3 actually 2 mols of H_2O do occur.

That the quartz does accumulate in the sand fraction and the kaolin in the clay, appears sufficiently from a comparison of the columns VIII and IX with XI, XII, and XIII. The silt possesses at one time more quartz (especially of the 50-20 mu. size), then again more kaolinite flakes (of 20-5 mu.). Taken by and large the mechanical (granular) analysis is not

Between the **ae** and **aq** weathering, there is interposed the amphibian weathering; the form of weathering of soils which stands under water in the rainy season but, in the dry season, remain dry. It is surprising to note how not only the **E** layer of some of these soils, but also even the **oE** layer in the rainy season becomes gray, yes even a bluish gray, while in the same place at the end of the following dry season the soil is again pale grayish yellow, permeated with reddish brown to dark brown threads of iron oxyhydrate. If for such amphibian soils one determines and states figures relative to the pH or the

121. C. P. Mom, Kaolin en Kwartszand., Meded. Labor. Agrogeol. en Grondond. Buitenzorg, No. 4 (1918), p. 3. (The table is slightly recalculated.)

content of ferrous compounds, then one ought also to record the month and season in which these figures were obtained; otherwise they have little meaning. For isn't it true that there is a periodical shifting of conditions and each half year later the values change?

If we once again restrict ourselves and this time to **V.b.I.--He.NN.am (I-5)**, then it is clear that there is not such a sharply outlined case as is designated by the extreme groups **ae** and **aq**. For in one place **am** can lie closer to **ae** and in another place closer to **aq**. And also the visible picture sometimes inclines more toward the one side, then again more toward the other. But yet for all **NN.am** cases, which are connected with **Nr.am**, this general point may be indicated: With an undisturbed situation there develops the flecked, cloudy bleaching in addition to the already mentioned precipitation of iron oxyhydrate. The latter occurs as veins of ore, for example along root canals, and as films upon sand grains which are sometimes knit together with this material. But the iron also precipitates in the form of independent concretions, beginning as grains of the size of sand or as "hail ore," growing to "bean ore" which then sometimes also coalesce to form larger chunks and layers. (See Frontispiece B.)

It is evident that not so much under **NN.am** should one search for those heavier and remaining precipitated forms as ore layers, but rather under **Nr.am**. And widely scattered concretions through the whole soil occur more under **NS.am**. Under these last mentioned conditions $CaCO_3$ also can precipitate. These various relationships appear in Table 54 (page 162) in which, as far as possible, the different continuous transitions may be traced from top to bottom and from left to right.

* * * * *

If we turn back to page 143 we will recall that in the pages following we always commenced with the parent material **V.b.I.**, introducing modifications one by one into the formula **V.b.I.--He.NN.ae (I-5)** thus:

1. from **He** toward **Ma**
2. from **NN** toward **Nr** and **NS**
3. from **ae** toward **aq** and **am**

And everywhere in the appended discussions of the resulting soil forms, in so far as there was anything special to be remarked about them, the stages **I** to **5** were considered.

Now we shall proceed to consider another parent material, which varies from good permeability with a moderate to small water capacity toward poor permeability or impervious, with a considerable to high water capacity.

The question of the differences in volcanic ash was referred to on pages 26 and 29. Aside from the question as to how far it is due to a differentiation of the magma, or to a sorting of the deposits through nearness to or distance from the volcano, the fact is that in each case in the Netherlands Indies extensive deposits of acid material, silicic-acid-rich and relatively poor in iron must have occurred in the form of extremely fine, almost white ash. This material then may be designated: **V.a.I.** (Cf. page 143). In the previously discussed formula of soil formation: **V.b.I.--He.NN.ae (I-5)** the **b** is now replaced by **a**; and at the same time the **NN** by **nn**, etc.

The water capacity of this fine, white ash is high and as soon as it has passed the weathering stages **I** and **2**, it no longer forms the very pervious brown earth, but a difficultly pervious, pale very plastic clay. During stages **I** and **2** the soil is still very pervious, and the humus as well as a little of the (brownish yellow) iron oxyhydrate still works wonders. (See Figs. 30, 31, page 163.) Let us therefore first consider **V.a.I.--He.nn.ae (I-5)** in its entirety.

Properly speaking the pure type, the most extreme case of the combination **nn.ae**, actually is difficultly attainable. For if the perviousness is bad, in a continuously wet climate the aeration of the soil cannot be adequate. Hence, one seldom or never comes across a uniformly brown or red soil, which at the same time is an impervious heavy clay. At most, intermediate forms between **NN.ae** and **nn.ae** which from plain brown or red become more

Table 54

EASILY PERMEABLE SOIL MATERIAL [1]

Parent material V. b. I. Temperature Zone: Me	Continuous downward Water movement Leaching out leaching out ↓↓ NN	Intermittent Downward Water Movement Leaching out Motionless ↓= Nr	Alternating Water Movement Leaching out Concentration ↓ ↑ N S
Subaerial weathering ae	E { First yellowish brown Then reddish brown then red eluvium or lixivium } without concretions continuously decreasing content of SiO_2, more gradual decrease of Kaolin mottled clay and later ore above white clay I (deep!)	E { first reddish brown then red eluvium or lixivium } without concretions mottled clay and later ore above white clay iron concretions I (less deep!) Ca concretions	oE (o I) dusty black Mn-containing iron concretions I (still higher!) Ca concretions → Gypsum →
Amphibious Weathering as	E grayish brown ↓ yellowish gray ↓ gray ↓ greenish gray ↓ bluish gray no hard iron concretions Reddish brown threads	E gray to black oE Many reddish brown threads Few iron concretions ore	oE (o I) black Sometimes still a few red threads Many Mn-containing iron concretions Ca concretions
Subhydric or Subaqueous Weathering aq	O on virgin terrain, ultimately: peat oE dark to light gray E bluish gray to white continuously decreasing content of free sesquioxides	O on virgin terrain, ultimately: peaty oE bluish black to gray I a few brown threads I { few concretions bog ore	oE bluish black with red threads and many Mn-containing iron concretions Ca concretions (bog lime)

1. For this scheme, compare: Meded., No. 16; Jg. 1931 der Meded. Proefst. J. S. I., Archief S. I. in N. I., III, p. 627. See also footnote 70, page 112.

Photo by Mohr

Fig. 30. South Sumatra; along the road from the Ranau lake toward Liwa. Fresh cut in liparitic tuff. Steep talus slope, for the gully erosion is much more vigorous than the erosion of the upper surface. For detail, see the following figure.

O

oE

E
▼
D

Photo by Mohr

Fig. 31. South Sumatra, along the road from the Ranau lake toward Liwa. Fresh cut in liparitic tuff. Profile:

O	about 1 foot.	Very much plant residues and little soil.
oE	" 1 "	Quite humous soil layer, already cemented.
E→D	-------------	Lightly weathered, going over rapidly into unweathered tuff, with a strong tendency toward gully erosion.

flecked in the direction of the "mottled clay," as they are more difficultly pervious to water and air. These intermediate forms are found quite frequently in Central Sumatra, in West Java, and in Borneo. They, however, do not always occur upon **V.a.l.**, as for example in Djambi, but upon other difficultly pervious parent material. But all lie between the uniform brown or red and the red or yellow flecked with white or pale violet, sprinkled with iron precipitates in all sorts of forms. As soon as stage **3** is reached both sorts are leached out, though the progress of leaching out of the bases is slower as the parent material is more acid and is correspondingly poorer in iron compounds. The soil types to which these processes lead would in Central Europe be called "schwere letten," and there these types would be considered useless for any cultivation.

Thus nature exhibits all kinds of transitions between **V.a.l.--He.nn.ae (l-5)** and **V.a.l.--He.NN.ae (l-5)**. The flecked or mottled nature, which has been recorded, indicates a transition toward **V.a.l.--He.nn.am (l-5)**, thus toward a more or less amphibian weathering of fine, white, difficultly permeable ash. If the land slopes inward from all directions toward a depressed center, then the soil becomes submerged and remains standing under water, and in case a little permeability still remains we reach **V.a.l.--He.nn.aq (l-5)**. However if the perviousness has been entirely lost, then the formula becomes **V.a.l.--He.r.aq (3-5)**, for in the stages **l-2** such an imperviousness can hardly occur.

With the last named type we have a swamp soil with the surface horizon grayer, deeper, and more bleached. It is a solid, heavy, very plastic impervious clay, without either spherical iron concretions or layers of ore. If, however, the level of the swamp or lake oscillates more or less with the season, then there will be a deposit of iron concretions, but only close to the permanent water table, in a ring which sometimes goes dry. This, of course, more nearly corresponds to the formula: **V.a.l.--He.nvv.am (l-5)**.

With this last formula we now approach a much more important soil type, at least so far as its distribution in the Netherlands Indies is concerned. It is the peculiar black soil of the regions with a distinct dry monsoon. This soil is found in the eastern half of Java, on the smaller Soenda Islands, and there are great expanses of it in the southeastern part of Celebes. For one who is familiar with these regions it is surprising to stumble upon the following statement under the discussion of the tropical soil formations in the great Handbuch der Bodenlehre:[122]

"Blackearths. They develop in a hot climate through alternating washing out and concentration and belong to the arid soils. They are not further considered under this heading as they are treated in another place in This Handbook and in their entirety in the narrower sense are no longer to be considered as true tropical soils."

Harrassowitz, the writer of these lines, apparently therewith refers the reader to the chapter on "Subtropical Blackearths"[123] by Giesecke which is found in the same volume. In this discussion Giesecke treats the black soils of Bombay and Madras, of Morrocco, Sudan, South Africa, of Argentina and California all together, but he does not mention the Netherlands Indies. And how is that?--Must we consider the south of British India, between 20 and 9° North Latitude, and Soerakarta and Madioen at 8°South Latitude subtropical rather than tropical? If so, then the differentiation of these two conceptions according to latitude, the position of the sun, and the uniformly high annual temperature breaks down. I feel compelled to oppose this interpretation. According to my conception it is simpler and better to retain the old differentiation into broad zones, and in addition to recognize that also in the tropics soil formations occur which exhibit many points of agreement with soil formations which are developed in higher latitudes. It seems to me the essential conditions under which the "black earths" develop are less strictly limited by the latitude than by other

122. H. Harrassowitz, Böden d. trop. Regionen, Handbuch der Bodenlehre III, (1930), p. 369.
123. F. Giesecke, Handbuch der Bodenlehre III, (1930), p. 350.

factors, such as the periodical alternation of wet and dry seasons in the year. Consequently if somewhere in the tropics the conditions occur which prevail more generally in the subtropics, and which may even be found in the temperate zones, then in those places similar types of soils develop. But to refuse to call such soil types "true tropical soil types" will not do. All kinds of soils in the Netherlands Indies are a priori tropical.

The formula of the black soils now to be discussed is: **V.a.I.--He.nvv.am (I-5).** We begin with a fine pale ash which in the rainy season is saturated with much water. Through hydrolysis a pale weathering colloid first originates and the soil moisture in it, containing Ca and especially rich in Na, exhibits an alkaline reaction. In the dry season, which is at least 3 months, but mostly 4 to 5, but may even extend to 6 or 8 dry months (see Table 36 and Fig. 6) the moisture of the surface soil and even that from greater depths evaporates. The reaction becomes strongly alkaline, the pH moves up to 9. The first modest vegetation of grasses and herbs dries out. The soil moisture containing salts makes the soil "physiologically dry." In the following rainy season a part of the salts (sodium and calcium bicarbonate) becomes superficially leached out and is taken away with the surplus rain water that runs off. From the seeds and also from the root stocks which survived the dry season, a new, sparse vegetation springs up. In the following dry period the dying is repeated as a result of drought of most of the parts of the plants above the surface of the soil, while the reaction again becomes more strongly alkaline. Of trees only those sorts can succeed which can easily endure a reaction of periodically definitely alkaline nature, and in connection therewith, are more adapted to symbiosis with bacteria than with molds. Such are, for example, the Leguminosae and amongst them particularly the Acacias, whose strong roots are able to grow down deep into a difficultly penetrable soil. Especially A. tomentosa (Javanese: klampis) and A. leucophloea (Javanese: pilang) occur frequently on the black soils of Java and thus apparently excel in the characteristics mentioned. But also other plants frequently occur, such as Opuntias and Euphorbias. (See Fig. 34, page 167.)

Meanwhile the weathering goes on. At the expense of the crystals of feldspar and pale glass particles which are present, the weathering forms colloids which become continually richer in kaolin. The soil becomes richer in colloids, while the process extends deeper and deeper below the surface. The bases come in for attention as a cause of chemical displacement within the sphere of action, as also the silicic acid but not the iron, because the pH ranges between 8.5 and 7. If at the same time a predominating black did not obscure the soil color, this should be light brown, or after a long time more light red. Whence does that intense black color come?

The opinion proposed at one time that a large content of finely divided magnetic iron ore[124] should be the cause, was conclusively refuted by Harrison and Ramaswami Sivan,[125] who demonstrated that this mineral occurred in only a few of the many "regur" (black cotton) soils which they investigated, so the constituent causing the black color must be ascribed to something else. Still much earlier yet Leather[126] had spoken out regarding the black "regur," that neither could organic matter be the cause of the black color, since that soil possessed so little organic matter, and therefore he ascribed the color to some mineral or other. But what kind of mineral, however, was not clear to him. Perhaps it was graphite. This last was however contradicted by Oldham, who was unable to demonstrate any graphite. And so the final result of the experiments of Leather was this: The black matter is specifically light, lighter for example than kaolin. It is not oxidized by strong sulfuric acid but vanishes upon ignition and, if first extracted with acid, leaves behind a white ash. The conclusion of Oldham,[127] accepted by Harrison and

124. H. E. Annott, The nature of the colour of black cotton soils, Mem. Dept. Agr. India, I, No. 9 (1910).
125. W. H. Harrison and M. R. Ramaswami Sivan, Black cotton soils of India, Mem. Dept. Agr. India, Chem. Ser. II, No. 5 (1912).
126. J. W. Leather, On the composition of Indian Soils, Agric. Ledger, 1898, No. 2. Pp. 83.
127. Oldham, Manual Geol. India, p. 413. Also in Leather, l. c., p. 24.

Photo by Mohr

Fig. 32. East Java, North slope of G. Ardjoeno, near Tretes. Fan shaped fracturing of augite-andesite, mostly in thin plates which later are very subject to weathering.

Photo by Mohr

Fig. 33. North from south Celebes. Toradja lands. Near Rimboen, west from Makale. Through surface erosion exposure of the spherical exfoliation weathering of compact, old andesite. The original unity may be reconstructed from the three kernels in the foreground.

Photo by Mohr

Fig. 34. East Java. East from Probolinggo. Characteristic xerophytic hedge vegetation (Opuntia nigricans and Euphorbia tirucalli) on very dry black earth: tM--He.nvv.am.3.

Ramaswami Sivan[128] was that it must be an amorphous colloidal hydrated double silicate of iron and aluminum, a conclusion, to which Giesecke[129] apparently also was inclined. But this explanation appears to me as also untenable, for 1st such a colloid cannot withstand strong sulfuric acid, and 2nd upon ignition it cannot leave behind a white ash. Further research may soon shed more light upon this. Provisionally it appears most probable that the black substance is of organic origin, developed through a sort of "carbonization." But from what and through what, no one can today say. Only this much is well known, that the formation is dependent upon the reaction of the soil.[130] In an acid medium this color does not originate but it does in a neutral or alkaline one. Thus it is possible that bacteria, perhaps also other microorganisms, play a role in the formation of this black material, organisms, which in the oxygen-poor or oxygen-free surroundings borrow the necessary oxygen from carbohydrates and other plant residues, while they leave behind a residue rich in carbon.

Through the usual method of carrying out the granular (mechanical) analysis in the Netherlands Indies (a method which can be conceived of as a further elaboration of the earlier, American method[131]) a peculiarity came to light which neither the American method nor the present international pipet method makes perceptible. This peculiarity is that the black substance in the kinds of soil under consideration concentrates itself almost entirely in the fractions between 0.5 and 5 mu. The black particles are sometimes a little larger, up to 10 mu. Thus they are not finely dispersed. If they act as a colloid, then it is as colloidal agglomerates. The fraction finer than 0.5 mu. is, however, like glue, and also like it in color, being a dirty olive yellow. This fraction

128. L. c., p. 280.
129. F. Giesecke, Subtropische Schwarzerden, Handbuch der Bodenlehre III (1930), p. 343.
130. Br. Tacke, Die Humus Böden der gemässigten Breiten., Handbuch der Bodenlehre IV (1930), p. 157.
131. E. C. J. Mohr, Bull. Dépt. d'Agric. Ind. Néerl., No. 41 and 47 (1910 and 1911).

must be considered as the cause of the shrinking and cracking and of the hardness of the clods, concerning which I have published various data,[132] and to which in the subsequent portions of this book we shall again refer.

Here still the attention should be fixed upon the fact that the black substance does not originate gradually and in the long run from a previously present lighter colored substance or complex of substances, analogous to the formation of red iron oxide forms from yellowish brown iron oxyhydrate. The black color obviously originates directly. And that is also conceivable, since it is just at the beginning that the reaction must be most alkaline. And as alkali carbonate and calcium bicarbonate are very gradually leached out in successive rainy seasons, the pH must certainly fall to 7 and lower, through which the conditions for the formation of the black substance are completely eliminated.

After all, the "black earth" and the "red earth" stand close together in so far as a somewhat more rapid run off or leaching out of the alkaline soil extracts inclines the balance toward the red. A somewhat higher water capacity and a lower permeability hold the soil water and in the dry season cause them to evaporate. Hence the tendency is toward the formation of black soils. Thus in a locality which has slightly rolling topography with here and there somewhat steeper slopes toward brooks and creeks, one frequently sees the black color of the higher flatter portions, while, where the slope becomes somewhat greater and therewith the dewatering is rapid, red at once obtains the upper hand. All this with one and the same parent material.[133]

Among the numberless large and small centrifugal ridges which radiate from a volcano, one sees suddenly a single black spot in the midst of much red, or the reverse. Then upon closer investigation it has frequently been possible to explain these through small differences in the parent material. For example, a somewhat higher content of iron, or a somewhat coarser grain size and the color becomes red; a finer and somewhat paler ash, and the color becomes black. These differences are because each ridge has developed from a separate mud flow (lahar).

But--what once is black remains black; and what is red, remains red. Thus profiles were found where a layer of a few meters thickness of the composition **V.a.I.--He.nvv.am.4**, (black), lay upon a red layer, (**V.b.--He.NN.ae.4**) although sharply differentiated from it. (See Fig. 36, page 169.) Elsewhere, not far distant from this, a brown oxidized layer rich in rock (**V.b.2.--He.Nr.ae.2**) lay upon a couple of black, earlier deposits, each corresponding to **V.a.I.--He.nvv.am.2**.

Previous to discussing the profile development, it may first be remarked that the main soil form under consideration is as a rule characterized by the presence of lime concretions. Sometimes there are exceptions to this. One realizes that it depends upon the addition and the losses of calcium carbonate. That is whether the $CaCO_3$ precipitation will first grow to small grain-like concretions, which later increase to the size of pigeon's eggs or to those of a fist (but kidney-shaped), or whether the concretions and the smaller grains will again dissolve. Much depends upon the Ca content of the parent material. But still more upon the soil climate, in so far as the **nvv** of the formula approaches more toward **nn** than toward **ns**. Black soils, adjacent to red ones will in general exhibit fewer concretions than if they lie in districts where the dry monsoon is more pronounced and the material is rich in Ca. (See Fig. 35, page 169.) Taken by and large, on the same parent material, one finds in the east (i.e. on the Smaller Soenda Islands: Lombok, Flores, Timor) more concretions in the black earth than in Central Java.

The behavior of the iron is peculiar in these black soils. If a quantity of such soil is ignited in the air it becomes uniformly red; only if a deeper sample from close above the water table is taken, one will sometimes come upon small iron concretions (little spheres of at most

132. E. C. J. Mohr, Meded. Lab. Agrogeol. Grondond., No. 1 (1913).

133. This is often the case in Central India where the sharper slopes in the black cotton soil region have dark brown soils. --Translator.

Photo by Mohr

Fig. 35. Soerakarta, Modjo sugar central district. Black earth profile. 50 meters from profile shown in Fig. 36.

Photo by Mohr

Fig. 36. Soerakarta. Modjo sugar central district. Black earth profile above a red earth profile. Only 50 m. from the profile shown in Fig. 35.

1 mm. diameter), which then appear upon ignition as little blackish red bits. This agrees also with the explanation of the origin of the black soils: in an alkaline or neutral medium the iron is not movable. Only when the climate is so moist that nvv inclines more toward nn and the lime concretions disappear, does one see the brown flecks and threads developed upon the broken surfaces and cracks. This indicates amphibian weathering nn.am and more iron concretions begin to form. But then the pH in these washed-out black soils is locally sometimes much lower than 7.

The peculiar shrinking and cracking of this kind of soil is a phenomenon which, in the dry season, impresses every observer. The obvious conclusion is that the iron in this soil, in spite of its fine division, must be present in still another form than in the brown lixivium soils. Otherwise it would make the soil more crumbly, so that the larger cracks would not be noticed. The iron may thus not occur in the so-called 10th fraction of the granular analysis (1/2 mu.). This also agrees with the results, since the color is not brown or brownish red, but, as already stated, is a dirty olive yellow. This means that the small amount of iron present has withdrawn from the most colloidal fraction into the coarser fractions, and thus leaves the great plasticity and stickiness of the finest fraction unaffected. So the cracking is understandable. The cracks may sometimes be several cm. wide, so that one's foot can get stuck in them. And since a cane can entirely disappear in them, the depth of the cracks often is 1 m. or more. However, large blocks lying on the surface do not usually remain entire. This is the case only when the soil is still loamy, that is, when the soil still possesses much unweathered material of 5 to 50 mu. When the content of plastic, shrinking clay is greater, then the large clods, too, break down into small ones, and these again into still smaller, so that the fierce sun finally shines upon only rounded heaps of very small cubical particles.[134] If now a strong dry monsoon wind blows over this slaked soil, then many fragments and angular grains are moved and fall into the deep cracks; thus much surface soil goes directly into the subsoil. As the rainy season follows, the whole soil swells upward, but what fell into the cracks as dry grains, for the time being does not get to the surface.

Hence it is clear that a succession of horizons in the uppermost meter cannot persist; each year they would again be disturbed. Hence the profile is practically homogeneous to the depth of the annually occurring cracks. However beneath that many times one finds an horizon of more white lime concretions. And in the still deeper black soil underlying the concretions down to 3 and to 4, yes even 7 m. are white flecks of considerable dimensions. These are cloud-shaped lime precipitations in cracks, which in the long run, because of the very slow leaching out and shrinking of the total soil mass, are bound to occur. A schematic development of the black-earth profile may be found below (Fig. 42, page 174).

An apparently more effective reason for crack formation in thick layers of black earth lies in the following. The mass is in a moist state, and so at a few meters depth it remains plastic. Therefore it has a tendency to <u>bulge out</u>, whenever there is an opportunity for that. Such is the case, for example, along rivers and creeks which flow down through larger or smaller ravines. The consequence is that at the commencement of the rainy season the soil mass swells and presses outward in the direction of the least resistance. If along the river great masses of earth fall, particularly conspicuous are those smooth, vertical breaking planes, where now and then are exposed the above-mentioned cloud-like white $CaCO_3$ flecks. (See Figs. 35-40.)

In such natural profile cuts we can see at the same time how the black horizon, even if it is many meters thick, quite suddenly, within a few decimeters, goes over into the underlying white or pale tuff D. A good example is along the Madioen river. At the boundary of D_1 (porous, and at most one to 2 dm. thick) and D_2 (a harder tuff with silicious cement) one comes across a strongly branched concretionary lime layer which reminds one of coral. (See Fig. 41, page 173).

134. In practice this is often spoken of as the "cauliflower structure."

Photo by Mohr

Fig. 37. Madioen. Redjosari sugar central district, near Poespoes, along the Kenteng river. Black earth profile from acid eruptives.

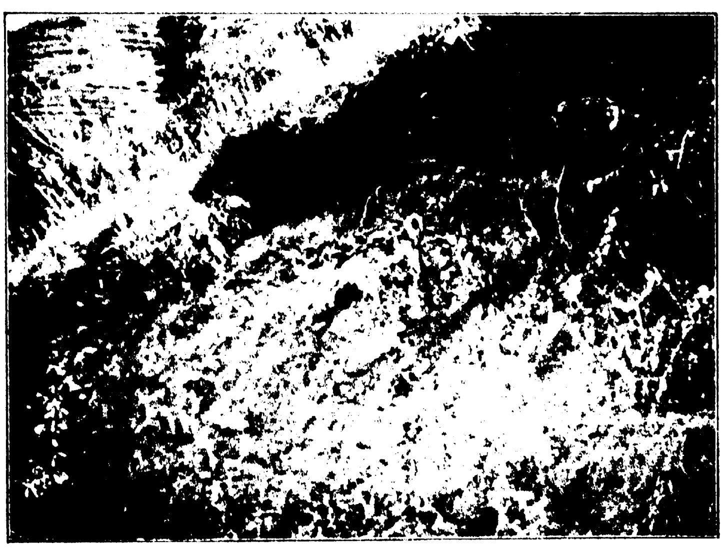

Photo by Mohr

Fig. 38. South eastern Bali, Karangasem, along the road between Manggis and Boegboek. Abundant precipitation of lime between (older?) zeolites and chalcedony. Parent rock: old basic eruptives. Soil: black earth with a slight reddish tint.

Photo by Mohr

Fig. 39. East Java. Seloredjo sugar central district, near Modjowarno. Channel excavated through black earth **V.a.I.--He.nvv.am.3**. At the right: the black earth has already slid off; a block of tuff with a white surface of concretionary lime has broken out. At the left: through sheet erosion of the black earth the white lime concretionary horizon is exposed.

If we now survey the whole picture of this black-earth formation, then the similarity with the British-Indian "regur" is indeed quite close. At Pasoeroean in 1930 I met Dr. L. C. Coleman, Director of Agriculture, Mysore State, who entirely confirmed this opinion. The following year I found the same soil type again in North Bali, in Central Lombok, in Central Flores and South Celebes, so that it is quite widely distributed, but still quite closely tied to the climatic requirements: **He.nvv.am**. Dr. R. Brink drew my attention to the fact that this soil was seldom found higher than about 200 m. above sea level. Thus the designation **He** in the formula is certainly quite accurate, at least for the Netherlands Indies.[135]

* * * * *

Where the fine, pale ash accumulated under water and weathered according to the formula: **V.a.I.--He.nn.aq.(1-5)** the above-mentioned flecked red coloring could not develop, and where **nvv** replaces **nn** neither can the identifying black color develop.

In the first case the weathering progresses through the stage (**2**) of black loam in the direction of a grayish white, stiff clay. In the latter case in the stage **2-3** the precipitation of some lime in the form of concretions is possible. There concretions, however, again gradually disappear in the stage **4-5** and are later replaced by iron concretions, which of course are preceded by a lowering of the pH from above 7 to noticeably below that.

As to how in such kinds of soil sometimes dirty olive green to dirty

135. Five years in the "black cotton soil" region of Central India leads me to confirm this opinion. However, much of this soil in Central India and the Deccan lies between 200-600 m. (800-2,000 ft.) elevation. --Translator.

Photo by Mohr

Fig. 40. East Java. Seloredjo sugar central district, near Modjowarno. Along the canal excavated through the black earth. Above: black earth with downward an increasing number of loose lime concretions. Under that: a layer of snow white lime concretions. Below that: calcareous pale tuff.

Photo by Mohr

Fig. 41. Central Java. Madioen river, just up stream from the Djati dam. Profile: 10 m. deep, black soil: V.a.I.--He.nvv.3 ; then a horizon with many lime concretions (1--1.5 m.), then a branching network of lime on the underlying pale tuff. See p. 170.

COURSE OF THE WEATHERING V.a. (1 & 2)—He.nvv.am (1—5)

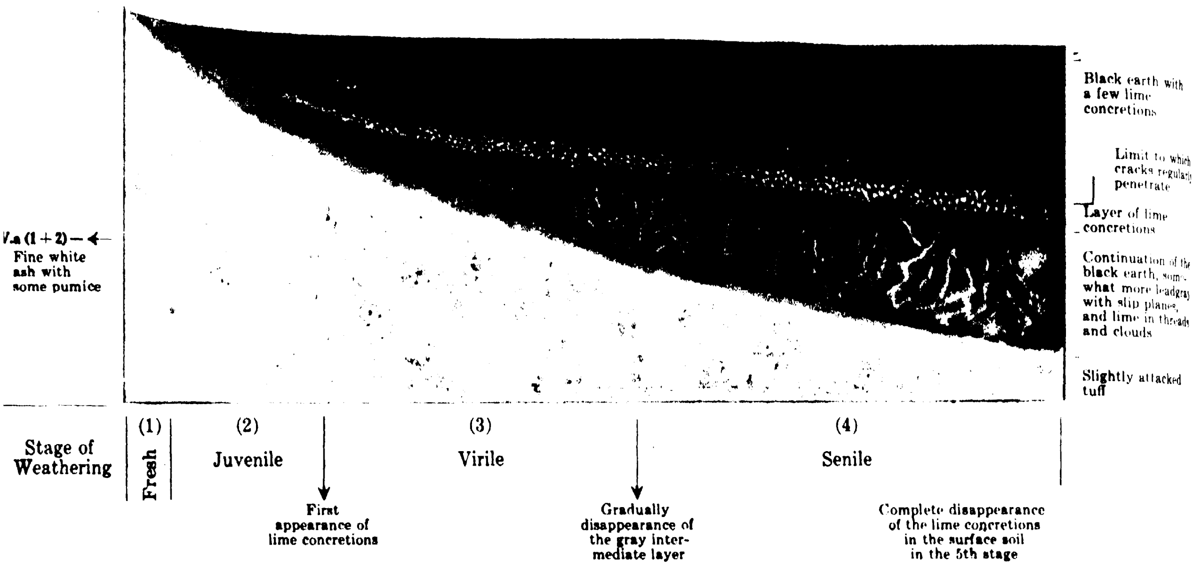

Fig. 42. Course of the Weathering V.a. (1 & 2)--He.nvv.am (1-5)

olive yellow colors come about will appear presently.

* * * * *

Let us now choose as further examples a few soils the parent rock of which is no longer purely of volcanic nature, but belongs to the original marine sediments, which have later become solid rocks (see page 11):--

1. Coarse sandy limestone, porous, pervious to air and water. Besides much $CaCO_3$, entirely or partially in the form of still recognizable organisms, it also possesses quartz sand, besides weatherable minerals as feldspar, hornblende and others, originating especially from volcanic or other igneous rocks. Location, for example, in Rembang. The formula then becomes: **zK --He.Nr.ae.(1-5)**.

If $CaCO_3$ were the only constituent, then no vegetation could exist upon this soil; for no plant can live on lime alone. The pure lime would be very slowly washed away in the rainy seasons, since there would be so little CO_2 to work on it, and no soil would remain behind.

But the sand of weatherable minerals, which weather in a manner similar to that which has been previously described (Chapter 3, pages 75 - 88), are mixed with the limestone. The lime which is present in excess is mixed with the residue and combines with it in two ways: 1) the colloids (clay) which are formed are to a great degree saturated with Ca, and 2) as a consequence the soil remains flocculated, and thus is abundantly porous for water and air. Now vegetation is quite possible. The greater the amount of weatherable sand which is present in the limestone, in the form of feldspar, amphibole, pyroxene, and dark glass, the more fertile the soil becomes, and the more luxuriant the vegetation. As a consequence of the great perviousness of the iron-rich accessory substances, an excess of water, however, cannot occur on the reddish brown soil developing on the limestone, which itself is also porous and pervious. But--when the drought

comes it becomes critical for the vegetation. Then the soil dries out and scarcity of water develops which for many plants signifies fatal conditions. Other plants can save themselves by shedding their leaves, the way the teak does. Still others come through the drought because of a relatively very small transpiration rate from their leaves and a large, deep root system. Meanwhile the brown color of the iron oxyhydrates changes quite rapidly toward the brownish red of the iron oxides containing less water (terra rossa). If the dry season, however, is less intensive, such as in the Southern Mountains of Java to the southwest of the Smeroe, then usually the color remains a characteristic liver brown.

When after the dry season the rainy season sets in, there comes to light still another effect of lime upon the soil. Coarsely dispersed and dry, with the first heavy shower the soil falls quickly a prey to erosion, and washes off from higher places into lower ones. (See Fig. 45, page 176.) In this way the higher parts of the limestone again become bare, while the lower are covered with a double depth of soil so that there the most vegetation develops. The highest CO_2 development in the soil is also there, and hence the most intensive solution of $CaCO_3$, the most intensive weathering of the limestone mountains occurs at these lower levels. The higher points weather the least, and thus become sharper and more conspicuous. Thus develops the characteristic profile of an Indian limestone mountain easily recognized from a distance (see Fig. 44, page 176). Faint depressions become deep pits, only partly filled with soil (dolines). Sometimes they form in the center a drainage passage toward subterranean caves and grottoes. Sometimes, however, the drainage is not so well developed, although the pit is already deep and the soil is thick, while the walls like those of the galleries about a stadium are for the greater part of bare limestone. With quite a rain, all the water flows down toward the middle and forms a pond, and the soil gradually becomes levelled off. Because of much vegetation and subaquatic or at least amphibian conditions the calcium carbonate is strongly leached and carried downward, so that the pH in the surface soil falls. Apparently sometimes the decrease is so much that now and then one comes across iron concretions in doline soils. Yet the continuous addition of Ca-containing material from the slopes prevents the soil from becoming permanently bleached to **am** or **aq** forms; it remains brownish red, though it can become heavier, since the iron from the finest subdivision goes over into a coarser dispersed form, by which the clay remaining acquires more plasticity and stickiness. If a runoff pipe develops under such a pond, the pond runs dry. The soil again becomes **ae**, and the flat topography together with the few iron concretions are the only things to recall the former pond. Yet the outlet may sometime again become stopped up. The pond then again comes into existence with all the consequences as sketched above.

If, however, the tuffaceous limestone weathers under distinctly **am** and **aq** conditions, then due to the lime of the subsoil, it is an especially favorable condition for the formation of iron concretions in the form of hail ore and bean ore (see Fig. 27, page 158). This is especially true if the climate exhibits a clear and long dry season.

If, besides the above-mentioned weatherable minerals, the limestone possesses relatively much quartz sand, then this will appear again practically unaltered as free sand. Consequently terra rossa formed in place is strongly sandy, while the soil which has been moved will, as a rule, possess less of it. Sometimes one of the two covers over the other; there are naturally all sorts of possibilities in this. However it should be added that in the course of a long time from a thick terra rossa rich in sand the finer red colloid fractions are carried downward through the soil, so that two definite horizons are developed; white quartz sand above, and reddish brown, heavy sticky terra rossa underneath.

* * * * *

2. Marls.--If in the scheme shown in Fig. 4, page 12, we now go from the left part over toward the right, we then find mixtures of the three principal kinds of

Photo by Mohr

Fig. 43. South Pasoeroean. Northern edge of the Southern Mts., south from Toeren. Liver brown lixivium on a cream to salmon colored limestone containing tuff sand: tK--He.Nr.ae.2. On the slopes the soil cannot become deep, because of intensive erosion and "dry wash."

Photo by Mohr

Fig. 44. Central Java. The Karangbolong Mts. from the northwest, near Idjoeh. Typical limestone mountain weathering profile with many sharp peaks and dolines.

constituents; (a) lime, in part as a very fine powder, in part as marine organisms (for example foraminifera, of different sizes, mostly between 0.1 and 0.5 mm.); (b) clay, which had been carried by the rivers to the sea, and there at first absorptively saturated in the sea water with Ca, Mg, K, and Na ions, thereupon flocculated and settled out; (c) fine mineral powder, not only pulverized quartz but also, for example, fine volcanic ash. With this, however, the whole story has not yet been told, for the clay and the fine volcanic ash do not sink unaltered in the sea; more about that on pages 184 and 189 ; here only the remark that in the mixed sediment which later becomes "marl," glauconite and serpentine-like minerals also occur.

If now a tuff mixture, as rock in a ridge of hills, weathers, then what will happen depends of course upon the climate, and especially the soil climate. Let us choose the case **tM--He.nvv.ae.(1-5)**, since this one (indicated by 1, 2 and 3 on the map, Fig. 6, facing page 60) occurs fairly often in Java. The tuff marl containing clay is difficultly pervious and although it takes up water, it does not allow water to readily go through. It is not the lime nor the mineral matter which takes up the water but it is the clay. When the clay swells, it regenerates into the condition which it had previous to the time that it reached the sea from the river. This does not happen all at once. The adsorbed metallic ions must be exchanged slowly with H and then the H-clay particles become hydrated, and some little time is required for this. Yet this change apparently proceeds much more rapidly than the taking up of water by non-calcareous clay stones and clay shales, with the consequence that the marls disintegrate much more rapidly. They become a clay gravel, which is extremely erosive. It is not at all necessary that a brisk stream of water flow over or scour along it. Even without this the mass which has become plastic slumps outward, and as a consequence it received the name of sliding soil.

Meanwhile the lime leaches from the surface layers of the soil during the rainy season. This is especially true if vegetation has established itself upon the soil, since it provides for a CO_2 increase in the soil moisture. The reaction remains, however, on the alkaline side, and the clay gives up but slowly the bases with which it is saturated. In the successive dry seasons however, there is no washing out. On the contrary, the pH moves up to 8 and higher while the soil dries out slowly, much more slowly than that on the previously referred to sandy limestone. As contrasted with the terra rossa (as on **V.a.I.** contrasted with soils on **V.b.I.**), there is a formation of some black substance, which obscures all other tints. Yet the soil is not the same. It is possible, yes even probable, that in the end **tM -- He.nvv.am.(4-5)** can no longer be clearly differentiated from **V.a.I.--He.nvv.am.(4-5)**, especially if the marl possesses much powdered tuff. But in the stages **tM -- He.nvv.am.(1-3)** there is still too much original $CaCO_3$ in the soil and in the neighborhood to permit a product to develop exactly like **V.a.I.- He.nvv.am.(1-3)**.

If the lime content of the original marl be very high, so that it might better be called a marly limestone, then the sliding seldom occurs. The water also penetrates less and causes less swelling. On the contrary in the dry season the drying out of the surface is more serious, with the consequence that the surface soil slakes down or crumbles. And if the dry east wind blows across it, much soil is carried along with it as dust. Wind erosion is also important. This phenomenon is especially notable in the whole region from Central Java to Timor and still farther east. On Soemba, for example, most of the soil formed in the rainy season is blown away as dust from exposed points of such marly limestone. This dust is carried into more protected depressions so that the limestone remains practically bare. These eroded places are but thinly covered with a few herbs and shrubs which have modest demands. In the following rainy season the ground washes off, losing material which would have been held in place by good vegetation. (See Fig. 20, page 140.)

We might here fix our attention upon one peculiar difference between many sandy limestones on the one hand and many marly limestones on the other. In the former it can be seen with the hand lens and under the microscope in thin sections, that calcite crystals have grown through the mass with disregard of all kinds of

boundaries; sometimes from one piece of an organism into another, in spite of the fact that the original forms can still be easily seen. In this way the limestone in a certain sense has become still more coarsely grained than it was before. In the latter, the marly limestone, no large calcite crystals can be seen, but under high magnification much fine calcium carbonate powder is visible. This looks like "craquele," or like broken rice grains, where each grain, as it were, has a dimly discernable film about it. One obtains the impression that the calcite kernels of the grains cannot grow through these films. If these films that are precipitated upon the grains are flocculated clay, then it becomes conceivable that such a granular lime marl in fresh water rapidly disintegrates to a loam, very rich in Ca, of great plasticity, and with a tendency to bulge out, as soon as the $CaCO_3$ content is sufficiently decreased.

Where the rainy season is not too short and the dry monsoon is not too long (see 3 and 4 on map, Fig. 6, facing page 60), a considerable vegetation can develop on the marls. Even forest may grow, though many sorts of trees in the dry season lose their leaves. The layer **oE** (**ol**) is black; there is hardly anything of a thin **O** layer above it. With depth this **oE** (**ol**) layer gradually changes, but very irregularly, without sharp horizon separations, over into **D** and the latter again into **P**, the still solid unweathered marly limestone. The layer **oE** (**ol**) has been given this double designation, since in stages **2** and **3** many times one comes across fragments of slightly weathered marl besides newly formed lime concretions.

During their life some Foraminifera (Rotalias) seem to have fixed a good deal of sulfur. In the thin sections their bodies are seen to be full of minute pyrite crystals in the midst of other organisms (Globigerinas), which are completely free from crystals. When marls with many such sulfur accumulating Foraminiferas weather, the pyrite oxidizes and sulfuric acid goes into the soil, and at the boundary of **oE** and **D** at, for example, a depth of 1.5 to 3 m. or in the lowest part of **oE** (**ol**), at 0.5 to 1 m. depth, there occurs at times a considerable precipitation of gypsum.

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§ 6. ALLOCHTHONOUS SOIL FORMATIONS

Besides the many kinds of soil forms originating in place, principally through chemical action upon parent materials (the soil formations which are called residual or sedentary), there are also those kinds of soils which originate through material coming from elsewhere, followed by the aggregate deposit of separate solid particles or larger pieces of minerals of rocks which then together form sedimentary deposits.

Water and air in movement, that is, currents and winds, are the forces which cause loose material to move, and again deposit it. They move the soil material from its primary place of rest to a secondary one. However since the words primary and secondary are also used in another sense and, especially in geology, already have another and fixed significance, it is better that their use be avoided in soil science. It is preferable to use the terms "authochthonous" and "allochthonous"; authochthonous being something that is in the same place where it has originated; and allochtonous refers to a body which occurs upon another place than where it acquired its existence as such.

Taken strictly, each soil with a profile peculiar to it is authochthonous; but the material from which it has been built up may be authochthonous or allochthonous. All kinds of sedimentary soils are thus formed from allochthonous material; but from the moment that these materials come to rest they do indeed again weather authochthonously.

Further, in the sediments we should differentiate between the following groups of constituents:

a. unweatherable minerals, such as quartz;
b. weatherable minerals, such as feldspars, pyroxenes, glass;
c. minerals which have resulted from weathering, such as clay, kaolinite, brown iron ore;
d. new formations, such as peat, coral sand, etc.

The nature and the composition of the sediments, qualitatively, depend upon the origin, the manner of transportation,

and the manner of deposition. Let us begin by separating water and air transportation.

* * * * *

WATER DEPOSITS

Apart from what becomes dissolved in water and for the great part is carried toward the sea in this form, we can differentiate three forms of transport of solid materials:

1. Water and solid materials form together a more or less porridge-like mass which flows downward with a high average speed, while within the mass from place to place and from instant to instant there are great differences in speed. This turbulent movement exhibits all possible rotations on horizontal and vertical axes and the power of transportation is enormous, both as to the total quantity, as well as to the size of single blocks of stone, which may even reach several cubic meters in volume (see Fig. 46, page 180). This catastrophal phenomenon, which is designated in the Alps by the names "Muren," or "Murgänge," in the Netherlands Indies is called "lahar" (Central Java), or "besoek" (East Java).

Lahars (mud flows) occur especially when extraordinarily heavy rains have so saturated with water a large mass of fine and coarse loose material, that it can move. Once this has started, it continues with increasing speed, taking with it in the devastating stream everything that the mass meets in its path and which is not securely anchored down.[136] (See Figs. 45-50, pages 180-182).

The lack of all differentiation according to size of grains is characteristic. If a lahar has been just as suddenly stopped as it originally started, one may find in a certain volume, say in one cubic meter, particles of 5 mu, as well as sand of 1 mm., or large stones of 5 dm. diameter. Eye witnesses state that large boulders of more than a cubic meter seemed to float on the mass. Hence when a lahar comes to rest, deposition in layers is out of the question. From the standpoint of soil science the material is truly chaotic.

When a lahar flows out into the plain, where it can spread out to a much greater width, there is a decrease in thickness (height) and a reduced speed. Then there is also a first differentiation. That is, the very big boulders and stones remain in the middle, lying more upon than in the lahar, and the farther one goes toward the sides, the stones become smaller and smaller. For this reason Coert[137] differentiated lahar centers and lahar edges, and hence differentiated the soils of lahar centers and the soils of lahar edges.

As soon as a lahar comes to rest, the water within it has an opportunity to flow out and to take with it all sorts of solid material. If it rains briskly upon the lahar, this rain water carries on down stream "after-lahars" which results in a deposition of the coarser material upstream, and the finer is deposited farther down. (See Fig. 48, page 181.)

The mechanical analysis[138] data indicate a general distribution of the various sized particles, there seldom being less than 5% and/or more than 15% of each fraction from ½ mu to 10 mm. and larger.

As soon, however, as by more water, a differentiation of the constituents of the lahar (from gravel to powder) commences, we come to another method of transportation. Water and solid particles (at least the coarser) no longer form one phase with one method of moving along, but two phases: above is the water with particles in suspension, and beneath the gravel and sand. We have thus to consider: swimming or suspension transportation, and rolling transportation along the bed of a stream of water.

In each stream of water in nature there can be distinguished two sorts of

136. Cf: E. C. J. Mohr, Over Efflatagronden, Teysmannia, XX (1909), p. 287-297; J. H. Coert, Over eenige grondsoorten in Kediri. Meded. Proefst. J. S. I., No. 21 (1926), p. 853-884; Vulkanol. Meded., No. 2 (Kemmerling), and others.

137. Coert, l. c., p. 857-863.

138. Compare also: E. C. J. Mohr, Ergebn. mechan. Anal. trop. Böden, Bull. Dépt. Agr. Ind. Néerl., 47 (1911), §37.

Photo by the Netherlands Indies
Army Air Service

Fig. 45. Central Java. Airplane view of the Merapi, from the Kedoe side, after the eruption of Dec. 1930. Left: Lahar of more acid (pale) eruptives; central foreground; lahar of more basic (darker) material. Right from that: portion covered with vegetation and inhabited. Left, more to the side: somewhat older, yet above also bare lahar terrain, sharply cut up by gully erosion. Left in the distance: Mt. Merababoe.

Photo by H. J. Coert

Fig. 46. Kediri. After the Kloet eruption of May 1919, a lahar come to rest with great boulders on it. Kali Poetih near Garoem.

Photo by Mohr

Fig. 47. Central Java. Very recent lahar field, close by the Blongkeng ravine. West side of the Merapi (after Dec. 16, 1930). Among the boulders and stones one is able to distinguish clearly the darker more basic, and the acid, white ones.

Photo by H. J. Coert

Fig. 48. Kediri. After a cloudburst over a lahar near Karang Nongko, 8 weeks after the Kloet eruption of 1919. Abrupt end of the stream of almost pumice-stone-like, porous andesitic cobble stones.

Photo by Mohr

Fig. 49. Southern Celebes. A cloudburst in the Mata Allo near Enrekang. Water of a dirty purplish gray color. Speed of the stream up to 8 m. per second.

Photo by Mohr

Fig. 50. Kediri. Bed of the Konto river near Keling, with a pier of a destroyed bridge. Coarse and fine colluvium of Kloet material. (V.b.2)col . unweathered.

Photo by Netherlands Indies Army Air Service

Fig. 51. West Java. Vertical airplane view of the lower course of the Tjitaroem. Along the river: overwash of pale sand, on which are few trees. Left above, and right below: deep swamps with black peaty water. Right: commencement of the laying out of swamp rice paddies.

movement: (1) a direct, straight line movement and (2) numerous eddying movements round horizontal axes, brought about by obstacles on the bed of the stream, or along more or less vertical axes, caused by irregularities in the condition of the banks of the stream.[139] The latter, the eddying, whirling movement is the one which especially causes the lifting up and bringing into suspension of solid particles; the former movement can only carry forward, not lift up.

2. That which is transported in suspension is ordinarily called "silt" or "sediment" (slib); when the speed of the water is lessened it sinks. If there is only a slight decrease in speed, then only the coarsest particles of the silt (sand) sink and join with what is being pushed along the bed of the stream. For the greater part the fine silt sinks only in practically still water, for example in flooded low plains and in the swamps of the low coastal tracts. However there then remain extremely dispersed colloids still in suspension. These precipitate only if in a long rainless period all the water evaporates.

The grain size of "silt" includes dimensions from submicroscopic to at most 1 to 2 mm. It is worthy of note that even with stream speeds of 6 to 8 m. in spate (bandjirs) (see Fig. 49, page 182) in large and deep rivers, of the material in suspension only a few sand grains exceed 1 mm. diameter, while along the stream bed large numbers of stones and boulders as big as tea chests are moved forward with great ease. Yet even in such streams there are apparently still enough relatively quiet corners along the bed and the shores where coarse sand and gravel can settle out, and these do not afterwards go into suspension.

If such a river in spate overflows its banks, then outside the natural levee formed by the pushing up and pushing over

139. L. Rueger, Tätigkeit des fliessenden Wassers. Handbuch der Bodenlehre I, p. 230-242, wherein are numerous references to important literature.

Photo by J. G. van Setten

Fig. 52. Palembang. High river bank along the Moesi, with the following profile:

oE =	1--2 ft.	Humus, dark brown surface soil. Crumbling but bound with roots.
E =	5--8 "	**al--He.NN.ae 2/3**, Crumbly, brown to red. Dry wash!
	6--8 "	Flecked transition.
E+I =	4--6 "	**al--He.NN.am/aq.3/4** . Heavy, slippery clay, pale with flecks; less subject to erosion, hence bulging out.

of coarser material, called "turn up," the water quickly deposits as a fine sandy loam the coarsest of the silt. Thereafter follow loam, then heavy loam, and finally clay (see Fig. 51, page 183, and Fig. 52 above).

If, however, the silt is carried on by the river to the sea, then as already recorded on page 130, it there becomes saturated with bases, and is flocculated out.

3. The material which is transported by shoving and rolling along the bed of the stream is called in German "Geschiebe." We cannot recall a suitable English word for this conception, though we speak of sand bars, gravel banks, cobble stone banks as designations for the observable phenomena.[140]

Such bars and banks are not stationary, but are continually rolled over and over. Far up the course of the stream they are eaten away. What the stream can move, it rolls against the bank, up and over the top, and down on the down stream side. In this way selection continually proceeds. What is relatively coarse is sooner left behind than what has a smaller diameter and is rolled along further. Thus a bank of mixed grain size (Fig. 50, page 182) gradually becomes purified from sand and fine sand and after having been worked over for a few kilometers acquires a quite uniform grain size (Fig. 48, page 181). Farther down stream, in quieter water, banks with components of smaller diameter

140. In "Geological nomenclator," edited by L. Rutten, published by the Geol. Mijnb. Gen. (1929) on p. 27 for Geschiebe "schuifsteen" is used. Except for the singular, used for one specimen, this word in so far as I know has not yet received general adoption.

move along until in the lower course, close by the sea, many times only sand banks appear to be shoved along. In reality the individual grains are rolled over and over. Continually the gravel and the larger stones are rounded off, smashed, or ground to pieces. The longer the journey continues the more the average diameter of the material shoved along ("Geschiebe") is decreased. Only short rivers with a rapid fall can carry coarse sand and stones into the sea.

With Marshall[141] we may differentiate three ways in which the mechanical weathering of gravel, etc. may occur:

(1) Scratching and scouring: This happens especially when the ratio of the diameters of the smaller and larger rocks or particles does not exceed 1:5-8.

(2) Smashing. Smaller gravel is broken by the larger; this occurs especially when the ratio exceeds 1:10.

(3) Fine grinding or pulverizing. This begins to occur especially with a ratio of the diameters of 1:25 and higher. In a gravel bank sand is not found, not only because it is washed away, but also because in a short time it would be ground up fine and carried away as fine silt.

The loss of material through smashing is significantly greater than through scratching, and the loss through fine grinding and pulverizing greatly exceeds that by smashing. Hence it is clear that while very much mixed gravel, such as that washed out from a lahar, after a time appears to have become coarser; the finer part is actually more reduced than the coarser.

If the material which is being pushed along the bed reaches the sea, then it can be further ground up in the surf and moved by the sea currents; but it cannot undergo such important alterations as the suspended silt.

In soil science, with reference to the method of transportation and deposit, many times the material being pushed along the bed is called "colluvium"[142]; and what was suspended, "silt," which after its deposition is called "alluvium." Apart from the method of deposit and the size of the grains, colluvium and alluvium may also be differentiated according to their nature. The fine alluvium is seldom juvenile in the sense that it still possesses unweathered but weatherable minerals. For the greater part it consists of products of weathering (clay) and unweatherable minerals in powdered form, such as quartz powder. Colluvium, on the other hand, when it is very coarse consists for the greater part of rock fragments still capable of weathering. Besides, when colluvium is finer, in addition to quartz sand, it consists also of sand of such minerals as augite, hornblende, and feldspar which, because of their ability to weather, give a juvenile character to the deposit.

From the viewpoint of suitability for vegetation the alluvium will, in general, exhibit a greater temporary fertility. Colluvium on the other hand begins by being infertile, undergoes, however, greater changes through disintegration and chemical weathering and in the long run delivers greater quantities of plant nutrients. A lahar unites these two good characteristics into one.

* * * * *

In many cases it can be seen from the curve of the mechanical analysis whether one is dealing with colluvium or alluvium,[143] and as to how the deposit has come about. Mention has already been made on page 17[illegible] regarding the curve of lahar deposits. This shows that coarse fractions are absent in the alluvium, and for the colluvium the finer fractions are lacking. From the form of the curve of an alluvial

141. P. Marshall, The wearing of gravel under beach conditions, New Zeeland Jl. Sc. a. Techn., IX (1927-28), p. 235; idem., Trans and Proc. New Zealand Inst., 58 (1928), p. 507.

142. Dr. George B. Cressey has called my attention to the practical disappearance of the term "colluvium," in present day geomorphology; the attempt is being given up to differentiate between colluvium and alluvium. In this book the two terms are retained in the pedological sense in which the author has used them. --Translator.

143. Worked out in: E. C. J. Mohr, Bull. Dépt. Agr. Ind. Néerl., 47 (1911), p. 30-46.

deposit one can see approximately with what speed the silt-containing stream has approached, and whether a sudden great decrease in the speed of the stream had occurred. If this is true, the curve includes many fractions. If a gradual decrease in speed occurred, the curve will include only a few fractions. At the same time alluvia from flowing water are to be differentiated from those from stationary water, in that the former have their tops at the left; while the latter most always have their tops in the finest fractions at the right.

Colluvia have their tops at the left, in the coarsest fractions. If the materials are but little "rolled out" then the curves are strongly assymetrical; steep at the left, while more extended at the right. The more the materials are rolled over and selected, however, the more the right branch is shortened, and the curve becomes a steep point, so that, for example, a curve for sea sand from a bar in the surf, is as steep as a lighthouse on both sides.

If a colluvial sand bank, consisting in part of quartz, and in part of feldspar and other weatherable minerals, becomes a victim of weathering, the lighthouse-like curve becomes less tall and less steep, while in the fine fractions a new peak rises in the curve. Thus there comes about a curve with two summits; one between 0.5 and 0.1 mm. and another at about $\frac{1}{2}$ mu. But by this time the soil has become an autochthonous soil from an allochthonous deposit (colluvium). The intermediate fractions of 5 to 50 mu. are almost entirely lacking. It is a sandy clay soil, or a clayey sandy soil; but not a loam!

* * * * *

In the preceding chapters the sediments and allochthonous soil forms have been included in one formula; a single formula from which can be deduced the parent material and the method of weathering.

The parent materials are the sediments, of which we have already obtained a general idea from the scheme on page 11 which is based upon the main constituents. In no sense in conflict with that scheme but from quite another viewpoint, that of the forming of the sediments, such as has been described in the few pages just preceding, the synopsis has been drawn up (Table 55, page 187). The parent materials in this summary are given as they should be employed in the formula. A few words in elucidation will not be superfluous.

In the first three vertical columns the method of sedimentation and the particle sizes are given for the silt curve. For soil formation, however, the weatherability or unweatherability is of the greatest importance, hence the subdivisions indicated in the 4th to 6th columns. The "unweatherable" group is more than 9/10ths quartz. Therefore this group is briefly designated by **Q**. And since the "weatherable" material in the Netherlands Indies is in most cases volcanic materials and rocks, the sumbol **V** is used in conformity with what was stated upon page 143. If it is possible to more accurately state whether the material is acid or basic, then one may use **V.a** or **V.b**. There should be no objection if one wishes to use the **V** more broadly to cover weatherable minerals and igneous rocks.

The lime is indicated by **K**. As in the case of **Q** and **V**, a fine form is indicated by a **1**, a coarse form by **2**. Solid coral limestone is also designated by **K.2**. Clay which for the greater part may virtually be considered the colloidal weathering product, is indicated by **Kl**.

Finally, alluvium is designated by **al**, and colluvium by **col**.

Thus according to this scheme we have 24 distinct types. In this connection it must certainly be kept in mind that sharp boundaries never occur. All forms which lie close to each other show transitional forms. Only the boundary between the first 12 groups and the last 12 is clearly marked, those between colluvia and the alluvia much less.[144] The lahar deposits, No. 25, show this very well for they are neither colluvium nor alluvium alone, but rather both together. Thus No. 25 (**V.1** and **V.2**) **col** falls outside the scheme.

144. See footnote 142, p. 185.

Table 55

TYPES OF WEATHERING OF SEDIMENTS

Name of the Sediment			The non-colloidal part of the deposit consists of: Entirely or for the greater part unweatherable (quartz, zirconium, etc.)	In part unweatherable in part weatherable	For the greater part weatherable (in the Netherlands Indies mainly volcanic materials)	Whenever hardened to rocks, the names of the sedimentary rocks are:
Fresh water sediments	Alluvium	Clay	(Kl) al -- (1)	(Kl) al -- (2)	(Kl) al -- (3)	Claystones slates
		Loam	(Q.l + Kl) al -- (4)	(Q.l + V.l + Kl) al -- (5)	(V.l + Kl) al -- (6)	Loam shales Loam slates
	Colluvium	Sand (banks)	(Q.l) col -- (7)	(Q.l + V.l) col -- (8)	(V.l) col -- (9)	Sandstones, Tuffaceous sandstones, Sandy tuffs
		Gravel (banks)	(Q.l) col -- (10)	(Q.2 + V.2) col -- (11)	(V.2) col -- (12)	Conglomerates Breccias
Marine sediments	Alluvium	Calcareous clay. Marly clay	(K.l + Kl) al -- (13)	(K.l + Kl) al -- (14)	(K.l + Kl) al -- (15)	Clay marls Marly claystones
		Calcareous loam. Marly loam	(K.l + Q.l + Kl) al -- (16)	(K.l + Q.l + V.l + Kl) al -- (17)	(K.l + V.l + Kl) al -- (18)	Fine sandy marls Fine marine tuffs
	Colluvium	Calcareous sand. Calcium carbonate sand	(K.l + Q.l) col -- (19)	(K.l + Q.l + V.l) col -- (20)	(K.l + V.l) col -- (21)	Limestones, calcareous sandstones, Sandy marine tuffs
		Calcarreous gravel. Limestone gravel	(K.2 + Q.2) col -- (22)	(K.2 + Q.2 + V.2) col -- (23)	(K.2 + V.2) col -- (24)	Marine conglomerates

It must be kept clearly in mind that in the first instance the synopsis (Table 55, above) deals with primary sediments. But also secondary sediments are possible. Thus, if the primary sediments harden to rocks (see the last column), and if these sedimentary rocks through subsequent folding or elevation come into such a position that they are exposed to weathering and erosion, then they serve as the source from which new, now secondary sediments can arise. Think for example, of the obviously pure terrestrial sediments of Rembang, Demak, and Madoera, among the constituents of which are sometimes many clearly recognizable fossils. These sediments could be placed with the marine calcareous ones. But then as such they would be secondary. In such cases the pedologist must choose, and he will be governed by what predominates in the character of the soil. As a rule the lime and the clay are the constituents which will especially turn the scale.

For there are clays and clays; both (1) and (13) of the above synopsis, as well as (3) and (15) differ in the nature of the clay. Mention of this has already been made on pages 130 and 184. And possibly (13) and (15) may have become

hardened to clay marls and these later again as mountains may become disintegrated by fresh rain water to clay and removed by flowing water. As long as there remains any free lime in the clay it will retain such a character (saturation by bases and flocculation) that even though it is a terrestrial or fresh water sediment the secondary deposit falls better under (13) or (15) than under (1) or (3).

We can go still farther. It is possible that a purely terrestrial sediment can originate from erosion products of **He.nvv.3** weathering, so that the latter possesses a large amount of calcium carbonate. Then it is possible that even though the constituents have never been in sea water, such a sediment is better placed with the lower 12, than with the upper 12. But in the Netherlands Indies these are still quite exceptional cases.

In the heading of Table 55, mention has been made of the non-colloidal part of the deposits as contrasted with the colloidal, which as we know from the preceding chapters, is a product of autochthonous weathering. From this we also know that, for example, Nos. (1) and (3) will be different; (3) will be much richer in iron. Here however, since it appears inexpedient in a general scheme to differentiate too far, (1) and (3) are both designated by (**Kl.al**). In especial cases one may know precisely with what he is dealing. For example, a certain valley is surrounded by nothing but andesitic volcanoes, which are covered with a soil: **V.b. --He.NN.ae (3-4)**. As the result of many heavy rains this soil continually erodes off to give a sedimentary deposit in a large plain (parent material) and it may be called **Kl.(al)**. But it may also be called **V.b--He.NN.ae(3-4) al**. One familiar with the subject would understand immediately that we refer to brown to reddish brown silt, without any quartz sand.

Sometimes, as for example in New Guinea, if one comes across a clay alluvium, about which nothing else is known than that a large river conveyed it from the mountains which lie behind, which are not adequately known as to formations and rocks, and about which one certainly does not know how much each contributes to the whole which is deposited as clay; then the naming cannot be carried farther than **(KL)al**--and the final working out must be left to the future.

* * * * *

So much about the sediments as new parent material; now something about their weathering and the soils formed from them.

By far the greater portion of these lands lie in the warm, hot lowland: **He**. Obviously, also, by and large, the finer grained the sediments, the farther down the rivers they are carried. While the colluvia are especially exposed to subaerial conditions of weathering, the alluvia as a rule remain under subaqueous, or at least under amphibian conditions. Consequently for the colluvia the often-occurring form is **ae**, and for the alluvia **am** or **aq**.

Whether for the latter the influences will be more **am** or **aq** is most often a question of climate. Where a quite strong dry monsoon prevails, there is a good opportunity for the severe drying out of the soil, which in the rainy season has water flowing over it or even is submerged for a considerable time. Where there never is a dry season, the conditions will be continuously of one sort, namely the terrain stands continuously under water. The alluvia are as a rule difficultly permeable, thus the most frequently occurring combinations are: **He.nn.aq** and **He.nvv.am**.

But colluvia can also occur directly under **am** or **aq** conditions; and alluvia directly under **ae** conditions. The latter is most often the result of important alterations in the flow of the river, such as a lowering of the mouth, in consequence of which the bed cuts down and lies deeper, and a previously overflowed plain becomes dry. But with such a change, however, the whole picture is altered, and such alterations do not easily lend themselves to classification. In the soil descriptions of the Netherlands Indies to follow later, we will come across various important examples.

* * * * *

The comparison of the allochthonous soil forms, originating from sediments,

with those which we called autochthonous, immediately brings out this great difference, namely that <u>from the beginning</u> the former <u>are fit to carry vegetation</u>. Consequently such a soil has a feature which, at least with deposits from a more or less stationary river, was lacking in the first stage; that is, a clear profile formation. Let us clearly understand what this means; not that in a thick layer of alluvium finer and coarser layers do not alternate with each other, but that there are horizons to be differentiated which signify something different, such as **O**, **oE**, **E**, **I₁**, **I₂**, **D**, **P**, (see page 121). In the beginning all of the sediment is **D**; or under some circumstances even **oD**, because of the simultaneous deposit of organic matter. Gradually in the deposit there will develop a differentiated profile. But then we are again dealing with an autochthonous soil formation, regarding which the reader is referred to earlier sections (if they relate to pure fresh water deposits, to pages 142-172 and in so far as they concern calcareous, secondary sediments from marine sedimentary rocks, to pages 172-178).

However, as soon as one comes within the influence of the sea the profile becomes different. Under such conditions many times upon a subsoil deposited in a lagoon or bay, thus as marine clay, there may be found higher layers which have been deposited by water which has gradually become fresh as has been the case with fresh water clay. So it is possible that in the greenish, flocculated and thus relatively loose marine clay at approximately 1 m. depth there occurs a pH of nearly 8, while in the solid, impervious river clay above it the pH falls to below 5, and even peat formation may originate above that. At a depth then, say of 4 to 6 dm., lies the horizon where the iron oxide precipitates as a layer of concretions (see Frontispiece B). In tracts with a strong east monsoon, coupled with drying out and cracking of the surface soil, lime concretions develop still deeper in the profile. These concretions come from lime farther down in the profile. This profile development can be observed especially well where a gradual regression of the sea is occurring. Thus where the land gradually comes to lie a little higher such as, for example, is apparently the case in various places along Java's north coast.

<u>DEPOSITS FROM THE AIR</u>

Especially after a prolonged residence in East Java (1930-1931) and a journey amongst the Smaller Soenda Islands, and certainly when having in mind the conditions in the entire Netherlands Indies, I cannot now entirely maintain my earlier position,[145] that on Java wind deposits play only a very unimportant role.

It is true that in the continuously wet tracts of West Java, Sumatra, Borneo, etc. the wind does not get much opportunity to get soil particles to move and to become suspended in the air, particularly since vegetation still protects the land. But where a brisk east monsoon kills the vegetation or at least the leafy canopy and also dries out the soil, the effects of wind transportation must not be underestimated.

For example, on Northeastern Soemba there is a very scanty soil cover on the bare limestone and marls. And the fierce continuous trade wind is the explanation: it has blown all the loose soil away.

Also here we can make a distinction as between "<u>air colluvium</u>" and "<u>air alluvium</u>," for close to the soil when the wind is blowing one can see the coarser particles of the size of sand grains skipping and jumping along. This is in a similar manner as the sand from the beaches of Holland rolls against the edge of the dune and hops up and over the crest, so that at last it comes to lie on the lee side, out of the wind. On Soemba the coarser material comes to rest on flat land in the valleys between the ridges, which in the wet season are apparently river beds, or at least soil levelled off by water. It was remarkable to observe, how, in July as the result of perhaps 3 months of wind action there had collected between the dried maize stalks on the darker soil a distinct grayish white thin layer of "air colluvium." The finer dust, "air alluvium" had however not

145. **Most recently in: E. C. J. Mohr: Tropical soil forming processes with special reference to Java and Sumatra (translated by Robert L. Pendleton), National Geological Survey (Peiping, China: 1933), p. 51.**

been deposited there, but had been carried on, far away, into regions where heavy rains brought it down from the hazy air.

How does this loose material which the wind carries away originate?--Through drying out sand grains are loosened. Dust and clay are loosened by the drying out and the development of great numbers of the most extremely fine cracks in consequence of the shrinking of the colloids. A slope which exhibits "dry wash" (see page 141), also becomes a prey of the dry wind. In addition, all forward moving rolling and hopping sand grains exert a grinding and scouring action just as does the sand from the so-called sand blast, so that projecting points of limestone or other rocks are reduced and worn away. In short--certainly without forgetting the ash eruptions of the volcanoes, there are ways enough for the wind to obtain its material.

In Europe and North America there have been carried out numerous measurements and weighings[146] of the quantities of dust falling in a definite time on a definite surface. In many cases it amounts to only a few tenths of a mm. for one single dry storm or during a month or a year. Now, for example, 1/2 mm. in a year is not much, but for 1,000 years it amounts to 1/2 m.; sufficient to give to a soil an entirely different character. In the regional description of the soils, examples of this nature will frequently have to be discussed.

In the course of a long time through the action of the wind, many autochthonous soils will be considerably blown out. That is, they will be robbed of their fine constituents valuable for vegetation. Other autochthonous forms of soil will receive additions of soil constituents. River deposits show constituents which cannot be identified in any of the rocks of the entire drainage basin; constituents which have been carried in by the wind over the mountain summits.

So where the wind sweeps over the soils it works continually upon all kinds of soils, forming and transforming them, sometimes making the explanation of the genesis of a certain soil extremely difficult. This is realized particularly if one finds vegetable or animal remains such as sponge needles, or silicious skeletons in the soil. How great the dangers of a wrong diagnosis may be, will appear from the regional soil descriptions.

* * * * *

146. E. E. Free, The movement of soil material by the wind, U. S. Dept. Agr. Bur. Soil Bull., 68 (1911), to which is appended an exhaustive survey of the literature.

Part II

THE SOILS OF THE NETHERLANDS EAST INDIES

PART II

BALI, LOMBOK, SOEMBAWA, FLORES, SOEMBA, TIMOR, NETHERLANDS NEW GUINEA

INTRODUCTION

In connection with the "Foreword," in prefacing the "Regional Description of the Soils" which follows we might here add a few words as to why, contrary to what one might expect, we have not begun with the most important islands of the Archipelago but have given preference to another order.

Regarding the soils of Java and Sumatra there has already been published "something of a general nature," but thus far nothing at all regarding the soils of the other islands. It is true that in the course of time several publications have appeared in which something has been said regarding the soils of certain localities but the information about the soils was always quite incidental. Besides, these comments taken altogether did not in any sense give one much knowledge of the Archipelago from the pedological viewpoint.

As regards the parent materials, the islands of "the Great East" exhibit a considerable diversity, which is in many respects in great contrast with the relative uniformity of parent rocks of Sumatra and particularly of Java.

Concerning the climate, in contrast to the rainy western and northern parts of the Archipelago, the relatively driest part is in the southeast, in connection with which in that region special types of soil may be expected.

So it was interesting for me when at the commencement of 1931 during my temporary stay in Pasoeroean, the Colonial Institute commissioned me to make another study tour for the benefit of this book; this was indeed an agreeable task. For this tour I chose those parts of the Archipelago which were expected to show divergencies from the usual conditions of Java and Sumatra, and which should exhibit extremes in certain directions. Thus the choice fell upon the smaller Soenda Islands and Celebes.

In the publication of the observations and impressions gathered in the course of this travel, it was obviously necessary to give precedence to those of the eastern islands. Moreover shortly before, on Sumatra as well as on Java, scientific soil surveys had been made and there existed the well-founded hope that use could be made of publications along this line in writing this book; hence another reason for treating Java and Sumatra last. As it turned out, however, researches in the field were stopped, budgets and personnel considerably cut down, and publications curtailed or abolished. Consequently in spite of the best intentions all but a few of the promises, so willingly given to me in 1931, to send on reports, photographs, samples, etc., from the Netherlands Indies, could not be kept.

* * * * *

Hence this "Regional Description" has been commenced with Bali and Lombok; thereafter follow Soembawa and Flores, Soemba and Timor. Then, New Guinea is considered because of the interest which it has from the standpoint of colonization. This is followed by Halmahera, Celebes, Borneo, Billiton, and Bangka. This order follows a circuit which is finally completed via Sumatra to Java.

It is true that numberless smaller and less important islands are still omitted. In justification of this it may be said that regarding the soils of these islands there is practically so little known that even today we cannot give any description of them. When the reader will have seen from the following pages how startingly little we know even now of the

soils of various of the larger islands, he will without doubt excuse neglecting those smaller islands.

* * * * *

BALI

Soil-Forming Rocks

The rocks which have contributed to the formation of the soils of Bali can be described very simply. On the geologic map[1] almost the entire island shows the color of "volcanic." In addition there are a number of plains--in the north three small ones along the sea, in the south one large one running from the west eastward along almost the whole mountain land, separately colored, as "Quaternary" but for all that the material is still "volcanic" in origin. Only the Prapatoedjoeng in the west-northwest consists of, or at least carries superficially a crown of limestone. This is composed of elevated coral reefs. The southern peninsula, Tafelhoek, consists of limestone of apparently Tertiary age.

The most important rocks are thus volcanic. They are all andesites and basalts. In addition however, there is much dark pumic stone material[2] which has come from Mt. Tabanan and Mt. Pengilingan, while Mt. Batoer in addition to augite-andesites and feldspar-basalts produced rather glassy basalts, and black obsidian bombs as well as white, olivine-containing pumice stone tuffs.[3] Also in so far as can be traced, Mt. Agoeng consists of feldspar basalts and pyroxene andesites both with and without olivine. Amphiboles do not seem to occur extensively on Bali.

In the course of an investigation in connection with the earthquake on Bali on the 21st January 1917, Kemmerling[4] made vulcanological studies of Mt. Batoer and Mt. Agoeng, and among his conclusions were the following:

1st. about two-thirds of Mt. Batoer is of loose volcanic ejecta; while the southern one-third consists of lava.
2nd. geologically the lava is younger than the efflata (fragmental ejecta);
3rd. besides Mt. Batoer I and II there are also some large and more small volcanic craters on the floor of the big crater, which ejected efflata almost exclusively.[5]

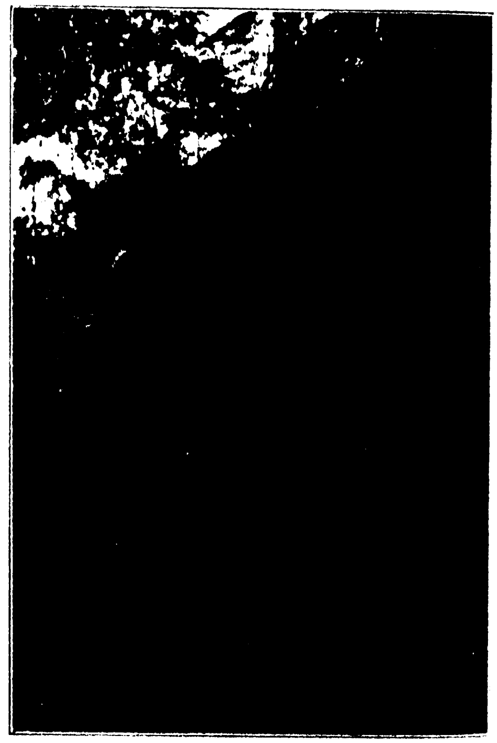

Photo by J. Straub

Fig. 53. Near the Brantan lake, Bali. Road cut through horizontal layers of fine efflata, in part of somewhat darker color. Upper center: weathering toward brown lixivium: **V.b.l.--Wa.NN.ae. (1-2).** Layer **0** absent, **OE** present. Deeper layers more or less cemented (by SiO_2) into tuff.

1. H. A. Brouwer, Geol. overz. kaart N.-I. Arch., Blad XVII, in Jaarb. Mijnw. N. O. I., 1915 Verh. 2e ged. (1917).
2. L. c., Toelichting, p. 38.
3. Report of C. G. S. Sandberg, referred to by Brouwer, l. c., p. 40.
4. G. L. L. Kemmerling, Jaarb. Mijnw. N. O. I., 1917, Verh. I, pp. 1-77.
5. L. c., p. 56.

Photo by J. Straub

Fig. 54. A road cut down through a weathered basalt lava flow near the Brantan lake, Bali. Loose efflata eroded off from the basalt is now brown lixivium: **V.b.2.--Wa.NN.ae. (1-2).**

The great quantity of loose efflatas, to be found everywhere on Bali, points to intense, explosive volcanic activity in earlier times (see Fig. 53, page 194). The lava streams both many of earlier as well as those during historic times (1849, 1905, 1926) are basalts (see Fig. 54 above). Without explosions the streams flowed down the slopes of, among others, the present day Batoer volcano.

Enormous indeed must have been those quantities of loose ejecta for it is a fact that in the walls of the incised, sometimes canyon-like, stream valleys (see Fig. 55, page 196) massive tuffs many tens of meters thick can be seen. These are composed of hardened sand and fine ash efflata rather than of coarse material such as gravel and stones.[6] For agriculture, and also for Balinese culture, this fact has been and is of paramount significance.

The lava eruption of the Batoer in 1926 was the inducement for an exhaustive research[7] by the Volcanological Survey, to which thanks are due for a number of rock analyses which are important for the study of the soil:[8] (See Table 56, page 197.)

It is not recorded whether these rocks were all water-free, or whether the analyses were calculated upon the water-free basis.

It is of importance to remark that the phosphorus content is strikingly low. Only in the pumice stone is it somewhat higher, as is that of the alkalies, while Fe, Ca and Mg are considerably lower, as was to be expected. Petrographically the lava feldspar appears to be rather toward the Ca-rich side. Even so, the K content remains favorable, namely around 1%. Where glass is observed in the rocks, this is described as brown or dark brown glass; such glass weathers relatively rapidly.

6. Kemmerling, l. c., p. 31, says: "We might with quite a good deal of certainty accept that the plain of south Bali consists of solid volcanic breccias in the deeper ground, but covered with Quaternary accretions, which can be estimated to have attained a thickness of from 100 to 200 meters.

7. Ch. E. Stehn, Vulkan. en Seism. Meded, No. 9 (Bandoeng, 1928).

8. Stehn, l. c., p. 37.

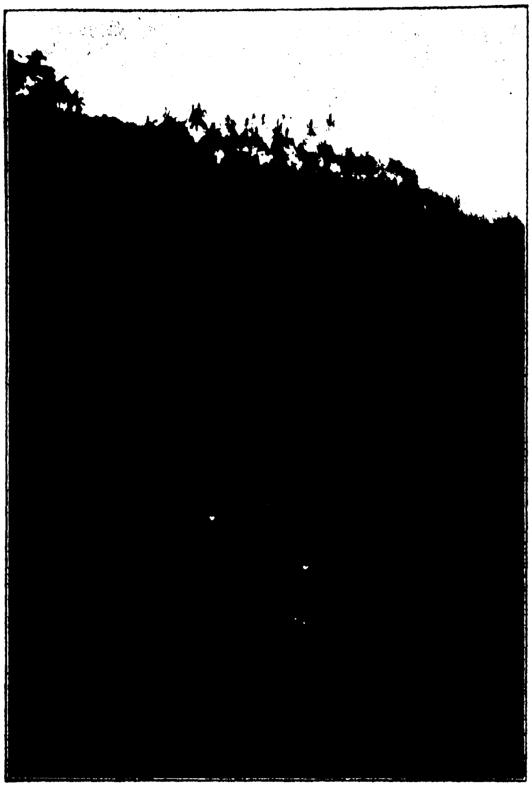

Photo by Mohr

Fig. 55. Canyonlike ravine in tuff, along the Rendang--Karangasem road, Southeastern Bali.

There remains to be recorded that along the edge of the lava of 1926 there were numerous fumaroles[9] some very hot, depositing products of sublimation, consisting almost entirely of ammonium chloride. This is an indication that the Balinese eruptives possessed a perhaps not-to-be-underestimated quantity of combined nitrogen which during the weathering or endogene decomposition of the rock was liberated as ammonium chloride. Where this salt, dissolved in rain water, comes into contact with vegetation, it must certainly act as an intensive nitrogen fertilizer.

Climate

The total annual rainfall in the lowlands, in the northern plains as well as in the great southern plain of Bali, is between 1 and 2 meters. Above the 100 m. contour line the rainfall rises to above 2 meters. Presumably there are places in the mountains where more than 3 m. of rain falls; but in those regions there are no meteorological stations which have figures for more than ten years of observations. Where these have already been collected, the averages of the annual rainfall are found to be between 1182 mm. (Singaradja) and 2538 mm. (Poepoean). Meanwhile the main point is the

Distribution of the rainfall during the year on Bali (see Table 57, page 197):

In considering these figures in connection with the soil we note the following: The northern coastal plains are analogous to those of East Java; they have a distinct but not long rainy period of about 4 months, and a marked dry season of about half a year. Singaradja is a good example of this: from May to November only with exceptional showers can rainwater from the surface pass downwards through the soil. (In this the lowland rice fields (paddies) irrigated with water from the higher tracts, are of course not included.)

The northern lower slopes of the volcanoes cannot carry any closed rain forest, at most only a park landscape (see Figs. 56, 57, page 198). That is, grassy plains with here and there a tree, since the soil cannot hold sufficient water to provide during a half year a closed forest with water.

Of course this applies especially to the ridges running out into the low land which are the old lava streams and heavy lahars. In the ravines in between some seepage water is sure to come out from the ridges and from above, and this supplies the soil adequately so that along these valleys a green strip of forest stretches farther to the north.

As one goes higher up on the slopes of the mountains in the rainy season more rain falls, and more rain penetrates into

9. Kemmerling, l. c., pp. 31-36.

Table 56

ANALYSES OF VOLCANIC EJECTA FROM BALI

	I	II	III	IV	V	VI	VII	VIII
	Lava of 1926							
	Upper course	Lower course Meneng Batoer	Lapilli 1926	Ash of 1926	Lava of 1905 at maroe of Batoer village	Lava of 1849 at Meneng Batoer	Pumice stone from terrace of Kintamani	Inclusions of pumice stone in foamy scoria of 1926
analyzed by:	Van der Grun	R. G. REIBER	R. G. REIBER	Van der Grun	R. G. REIBER	R. G. REIBER	R. G. REIBER	R. G. REIBER
SiO_2....	51.14	51.50	51.22	51.46	50.45	53.68	64.70	62.80
Al_2O_3...	20.15	20.35	20.18	20.24	20.66	20.88	15.60	16.58
FeO.....	7.27	7.65	7.41	7.46	8.90	5.45	2.13	2.46
Fe_2O_3....	2.98	3.14	2.62	2.59	2.34	3.27	3.72	4.82
TiO_2....	not det'd	0.24	0.15	not det'd	0.46	0.44	0.08	0.10
P_2O_5....	trace	trace	0.10	trace	---	trace	0.20	0.14
MnO.....	0.48	0.30	0.46	0.48	0.48	0.39	0.24	0.38
CaO.....	8.80	8.46	8.56	8.82	8.90	8.47	2.98	3.70
MgO.....	5.11	4.91	5.34	5.19	5.27	2.82	2.24	2.52
K_2O.....	1.06	0.83	1.16	1.02	0.58	1.27	2.79	2.08
Na_2O....	2.62	2.76	2.81	2.70	2.05	3.07	5.02	4.25
SO_3.....	---	---	trace	---	---	---	trace	trace
Cl......	---	---	----	---	---	---	0.03	0.02
H_2O.....	----	---	---	---	---	---	---	---
	99.61	100.14	100.01	99.96	100.09	99.97	99.73	99.85

Table 57

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON BALI[1]

Locality	Elevation above the sea in m.	No. of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Singaradja....	40	48	81	245	247	211	96	55	36	16	6	4	16	70	181	1182	4	6
Moendoek......	700	18	136	380	417	351	246	166	50	25	21	32	78	214	313	2295	7	4
Poepoean......	about 800	13	136	313	401	364	294	176	66	48	40	39	127	298	376	2538	8	3
Negara........	8	47	104	224	190	194	124	94	93	58	77	70	159	180	216	1678	7	1
Tabanan.......	130	23	122	386	298	262	151	131	109	109	133	98	226	266	366	2535	11	0
den Pasar.....	40	24	89	317	246	197	78	79	59	48	65	41	118	157	312	1717	6	3
Gianjar.......	120	18	99	265	210	187	101	104	118	117	123	69	159	175	264	1892	11	0
Kloengkoeng...	85	18	88	224	205	148	102	129	126	119	116	73	168	162	265	1831	11	0
Karangasem....	105	22	77	198	214	162	61	74	79	46	44	36	92	74	174	1254	4	3

1. Rainfall figures, taken from Verh. No. 24 of the Kon. Magn. Meteor. Obs., Batavia, p. 208, running through 1928, and corrected with the data relating to 1929 and 1930. Figures of later years were not published at this writing (1934).

Photo by Th. van der Paardt

Fig. 56. Mt. Lingker, Northwestern Bali. Typical natural park landscape. Here 5 to 8 months drought per year.

Photo by Th. van der Paardt

Fig. 57. View of the volcanic mountain range along the north coast from the peninsula Tg. Goendoel, Northwestern Bali. Park landscape on dry, eroded-off slopes; forest on deeper soil lower down the slope. The higher mountain land beyond is also well forested.

the soil. This water does the vegetation more good as the climate becomes cooler with the increased elevation. The trees now form groups, while still higher there is even closed forest. Unfortunately, due to the deforestation by man there is not now much forest left. Forest destruction has been especially serious in the central and eastern portions of the island, in particular on the northern and northeastern slopes of Mt. Batoer and Mt. Agoeng. In the west it is somewhat better because 1st, more west monsoon rain falls there, and 2nd because there is less flat land and in consequence the population is less dense. Here the slopes are still quite well forested.

Actually the southern plain consists of two parts. The western part in Negara extends to approximately where the highway coming down from the north reaches it at Antosari. The other part is the eastern plain--better called the central southern part of Bali.

Negara has indeed not much rain, not even 1700 mm., but even in the driest month about 60 mm. falls. This locality does not seem to have a sharp dry season, which reminds one of Banjoewangi (Java). Since Tabanan has much more rain (between Negara and Tabanan there are no rainfall observations), with not a single month with an average materially below 100 mm., this entire western part may be considered as continuously though for that matter moderately moist. Certainly the soil of this plain will not dry out very thoroughly.

Central Bali rises up gradually from the south toward the north. Hence as an ascending wind the southeast monsoon will first at Kloengkoeng and Gianjar be moderately moist. Higher up, against the southeastern slopes of the Peak of Tabanan and of Mt. Agoeng the increase of moisture and consequently of the rain must be much more marked. While there are no rainfall stations to prove this, the great number of rivers especially upon the southeastern slopes is evidence enough. This difference is exactly analogous to that on Java as may be observed on the slopes of Smeroe and Idjen. Lying to the west of Mt. Tabanan, hence in the rain shadow, Moendoek and Poepoean have, in spite of a total rainfall of 2248 and 2586 mm., a sharp dry season, which however has a less marked effect upon the soil because of the greater elevation (hence the lower temperature). The southern point of Bali also has a distinct dry period; as does the east at Karang Asem. But no single place in south Bali has such a distinct drought as does the north coast.

Little of the natural vegetation in south Bali remains. This is because the dense population and the intensive agriculture necessitate that the land be used either for lowland rice fields, or unirrigated cultivation, or pastures. But if there had not been the dense population the forest would be covering practically all of southern Bali. Perhaps in the extreme south and east a number of higher ridges and smaller steep mountains, however, may still be covered with some little park landscape! But even so no treeless savanna would be present.

Ways in Which Weathering Occurs and the Resulting Soil Types

Seeing that neither the parent rocks, nor the temperature nor the distribution of the rainfall upon Bali exhibits any peculiarities which have not already been described in the general part--we cannot here on Bali expect any new kinds of weathering nor any new soil types. Even so, there is sufficient diversity to justify a brief discussion. We can perhaps best start out from the sketch (Fig. [illegible], page 200), adapted from the publication of Kemmerling[10] already referred to above and which for our purpose gives an adequate view of the subject.

The unconsolidated volcanic products from Mt. Batoer have been ejected especially southwestwards. As a result of the east-southeast wind a portion has been deposited against the Bratan and Tabanan mountains, and by the rain water and through the numerous rivers originating there it has been carried southward (II). That portion of the ejecta which was carried beyond the ridge was similarly carried into the small northern coastal plain (VI). The ash which

10. Plate No. 1 belonging to Jaarb. Mijnw., 1917, Verh. le Ged.,--(in the atlas).

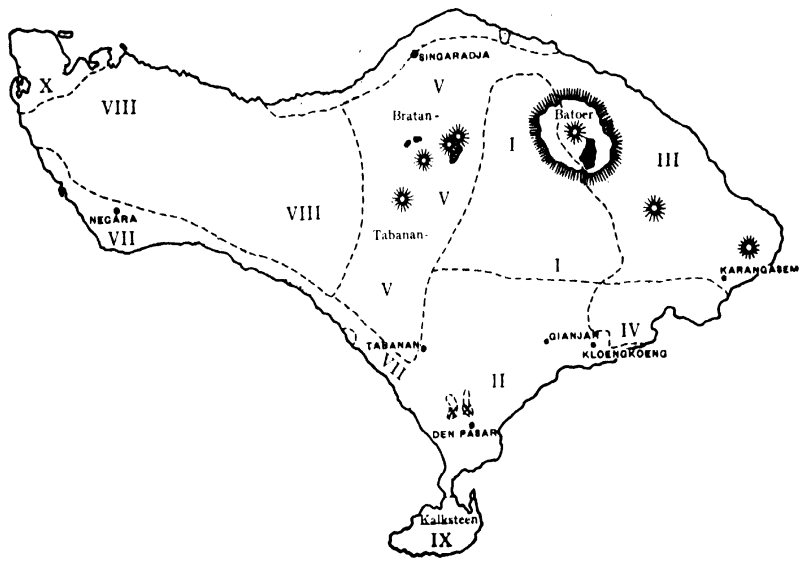

Fig. 58. Topographic and Geologic Regions of Bali. (I) Loose volcanic ejecta predominate. (II) The south Bali Plain of recent volcanic sediments. (III) Principally lava and other solid igneous rocks. (IV) The older Sidemeng mountains. (V) The Bratan and Tabanan mountains. (VI, VII) Narrow coastal strips of recent sediments. (VIII) Volcanic mountains of the Djembrana region. (IX) Limestone. (X) Limestone (?). --After Kemmerling.

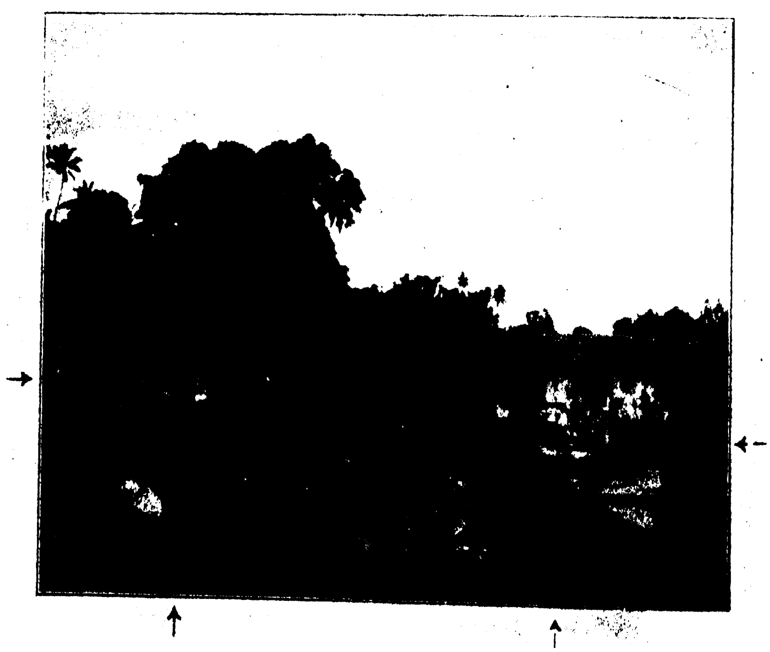

Photo by Mohr

Fig. 59. Ravine along the road toward Batoeriti, Southern Bali, where fine tuff for the sculptures of the temples is quarried.

landed upon the western outer slopes of the Batoer volcano itself was washed off toward the south.

In this way the character of the tracts I and II has already been directly determined. It is very juvenile soil material, more or less clearly layered, and only recently having started to weather via the subaerial, continuous lixivium weathering toward brown sorts of soil the formula of which is **V.b.I.--(He to Wa).NN. ae (I-2)**. This is the soil type which in East Java is frequently called "tarapan." But since in Bali the soil is yet very young the color is often grayish brown, and the consistency is very crumbly. In those places where for a long time no fresh ash has been washed over the soil, the color is more brownish red, the consistency is more cohesive and heavier, though still as a whole very pervious: stage **2-3**.

In the higher portions of region (I) the climate is pretty much without a dry period. In combination with the pervious soil material this brings about a continuous, although moderate water movement from above. The consequences of this are 1st leaching out of the surface layers, and 2nd causing formation of tuff in the deeper soil. Here in Bali there is much tuff. There is both coarse tuff (conglomerate), and also much fine tuff. The latter is the very much sought after and much used raw material for the abundant architectural sculpture of Bali (see Fig. 59, page 200). Nature favors the artist with the relatively soft tuff and through the rapid weathering she keeps the construction work going, which then must again be repaired, and so keeps alive the art of this people. If Bali possessed no more suitable material than does Palembang or Pontianak, the Balinese would presumably be no more sculptors than are the inhabitants of Palembang or Dajak.

The tuff is exposed and hence easily quarried by the natives in the river valleys everywhere. Most of these are canyon-like ravines, which later slowly widen themselves as the banks break down following under-cutting by streams.

The farther south one goes (II), the drier the climate, the more the weathering form shifts from that of continuous leaching into that of intermittent leaching (**W.r.**). While this leads to a similar soil type as does the first weathering type mentioned, the process is somewhat slower.

Still more southerly, particularly along the coast, occur lowlying bodies of soil where the subaerial weathering (**ae**) is replaced by the subaqueous (**aq**). Here the soil is gray, dark, and humous. When this soil is dried out it is gray with deep cracks; gray because of the much still-unweathered ash in it, cracked on account of the clay which is already in it. As a result of the subaqueous weathering it has been robbed of its iron and hence it is very plastic and heavy. The area of this soil is small; and since it is not yet free from salt, the only vegetation that it supports is mangroves and other plants which can tolerate salt.

In between these two bodies of soil, one with subaerial and the other with subaqueous weathering, there is sometimes found a very narrow strip with amphibious weathering (**am**). The greatest proportion of this, however, is found in the rice paddies, which since times immemorial have been cultivated in the same way. But since the soil of these paddies is in no sense rich in clay and impervious, this weathering form is not distinct. The water which is used on them to a great extent still sinks in, taking oxygen down with it in solution. As a consequence there is no definite periodically air-free or oxygen-free condition in this soil. Only on the most weathered, heaviest parts can there be observed on the fractures of the big clods of earth the well known brown veins and flecks indicating that during the previous rice growing season the iron had been movable, dissolved. This condition is observed only when the paddies are dry.

In tract (III) on the sketch map (Fig. 58, page 200) further weathered soil (stage **2-3**) is found on more solid rock. At least this is the case where continuously adequate rain falls, thus on the higher mountain slopes. But even there the soil is not brilliant red. It is not senile for ash-falls have now and then rejuvenated the soil, giving it a grayish cast. Especially the sediments in the valleys are more grayish brown.

More around the point toward the north, in the wind shadow, the more pronounced dry monsoon joins more strongly in

Photo by Mohr

Fig. 60. Looking eastward from the Rendang--Kloengkoeng road, Southeastern Bali.--In the foreground reddish brown lixivium in a more humid climate. In the distance; Sidemong mountain range, on the lower and drier parts (to the right) is also black earth. (See Fig. 38.)

the chorus. Here leaching becomes less and less, while in the short rainy period sheet erosion becomes dominant. Upon the slopes the result is a shallow grayish soil, granular, crumbling. Because of lack of water this soil carries little vegetation, at least in the lowest part along the northeast coast.

There is not much of any plain along the north coast but along this coast, with more water retained in the material eroded from the slopes, the vegetation does grow well. The soil seems to be fruitful enough, if there is water (see Fig. 60 above). The amount of the vegetation is at least in proportion to the rainfall. This is much more the case as one goes around the north toward the west where the wet monsoon from the northwest to west ascends the mountain slopes. That is, against the north and northweatern slopes of Mt. Panoelisan and Mt. Tjatoer. So here are much thicker forests higher up than on the eastern slope of Mt. Batoer and the northeastern slope of Mt. Agoeng. All the rain water which the soils above cannot absorb sometimes comes downward with great violence into the plain (VI). This plain would profit much more from the run-off from above if the lower slopes were not already so extensively deforested and brought under cultivation. During the long intensive dry season (see rainfall figures for Singaradja) it would be of inestimable value for the low land if the rivers still continued to carry some water and if the springs also supplied more water.

The weathering form is here intermittent leaching, resulting in the gradual forming of reddish brown lixivium. Whereas on the somewhat older Mt. Tjatoer this form has already changed into a more advanced stage. Everywhere is the usual reddish brown land, used as paddies or upland fields. As far as the climate is concerned, black soil might also be expected on the lower ridges. But relatively acid eruptives in the form of pale ash are

sought for in vain, and hence the black soil is likewise lacking.

However, indications in the direction of black soil development are meanwhile found in the environs of Karang Asem, that is, on the foot of the southern extensions of the older and perhaps also somewhat more acid mountains of Sidemeng (IV). In the more continuously moist back country of these mountains, hence more to the north, along the road from Karang Asem toward Rendeng, the soil is again the customary brownish red lixivium (see Fig. 55, page 196 and Fig. 60, page 202).

High in the mountains (in III, I, and V) the climate is of course much cooler, so that here the humus lasts much longer and in the old forest this colors the surface soil intensively brownish black. But where the forest has vanished this humous surface soil has everywhere washed off speedily, so that the present surface soil is a paler, brownish yellow.

The volcanic mountains of the Djembrana section in the west (VIII) are older than the volcanoes in the east. As a consequence we may also expect further weathered and less juvenile soils. And in so far as in the course of time the soil has not washed off or has not slid off en masse this is indeed the case. For this locality is very rugged. Deeply cut valleys run between steep slopes, and of plateaus there is now not much left (see Fig. 57, page 198, in the left distance).

But at the same time this part of Bali has not been undisturbed volcanically. It was apparently repeatedly blessed with rains of ashes from the surrounding volcanoes. Whether they were only those of the more easterly part of Bali or also those of the Idjen mountains of Java is difficult to make out at present. From the already steeply standing slopes much ash rained downward. This formed, in the lowlands, the plains of Djembrana and Negara (VII). Yet much ash remained behind in the forest on the mountains which rejuvenated the soil there. And if they were not so steep those mountain slopes would be a beautiful soil for cultivation. With an eye to the plain, it would now be better to leave the slopes intact. And since fortunately few people have settled on these slopes, it would be wise to prohibit any new land being taken up for settlement. For then there might certainly be a serious fall in the value of the above-mentioned small strip of low plain which at present is valued highly because of the extraordinarily high production of rice. With deforestation of the mountains, the rivers certainly would become much richer in silt and sand through the erosion of the surface soil of the higher regions. And at the same time the losses would become irregular, as upon the north coast, and in that evil hour they would see that they had killed the goose which laid the golden egg.

This consideration of the soil types, for the great part originating from efflatas of the volcanoes, ought not to be brought to a close without a few words devoted to the phenomenon very certainly important for Bali, i.e. the landslides and the earth falls in certain localities, as a consequence of the earthquakes. In this connection Kemmerling[11] has said with emphasis: "In an area of about 6[illegible]0 square km. (about 1/9 of the area of the island) hardly a single bit of ground has remained in its own place."[12] "In all ravines along all slopes....the masses of earth slid downward" (see Fig. 61, page 204). And Kemmerling wrote so emphatically after only one earthquake, which was of but brief duration. It is true that such earthquakes do not occur every day, yet in the course of ages, in the time necessary for volcanic ash to change into a virile or even a senile soil, they would certainly occur at least a few times. In other words the surface soil upon slopes has not had time and opportunity to weather out to senility. Before that comes about, the soil is again deposited in a ravine, through which a river flows, which disintegrates it and carries it away as silt and sand to lower locations.

This might explain why, in places built up of loose efflata originally perhaps from [illegible]0 to as much as 200 m. and more thick, the arable soil is so thin, if the

11. G. L. L. Kemmerling, De aardbeving van Bali op. 21 Januari 1917, Jaarb. Mijnw. N. O. I., 46 (1917), Verh. Ie Ged., pp. 1-50.

12. L. c., p. 15.

Photo by Kemmerling

Fig. 61. Environs of Koeta Dalem. Central Bali.--The landslide after the earthquake of 21st January 1917 shows that the whole ridge consists of loose efflata only slightly cemented to tuff.

places lie in regions exposed to repeated severe earthquakes. The conclusion need not necessarily be entirely correct that since slightly weathered efflatas lie so close to or right at the surface, the eruption from which they originated must have taken place only just recently. It is quite possible that the present day surface layer is not the 1st nor the 2nd but is already the nth since the original eruption.

In conclusion a few words regarding the soil of the limestone tracts IX and X. Tafelhoek, the southern peninsula, has without doubt--(it has no rainfall stations)--a relatively dry climate, since it is only 200 m. high. Van Roon[13] writes among other things "in the east monsoon an utter lack of drinking water prevails on the peninsula....the impression which this part of Bali makes is not particularly favorable but yet still somewhat less unfavorable than that of Noesa Penida, which especially in the east monsoon offers a most barren appearance. The only fresh water well is that of Tojapakeh on the coast. In the interior water is entirely lacking."

The soil on the limestone is also not thick. Everywhere the angular limestone points project up through it. It is a chocolate brown soil. Presumably the materials mixed with the limestone have been: 1st a little sea silt, which makes the soil heavy, after the washing out of the limestone; and 2nd some ash from the volcanoes (perhaps as a result of the direction of the prevailing wind, more from Raoen on Java, than from the Balinese volcanoes). This may explain the soil's red color and a certain fruitfulness of the scant vegetation, even though it is suffering from a lack of water on the Tafelhoek.

The limestone is however a porous rock, which takes up superfluous rainwater in the rainy season and allows it to penetrate deeply. Hence there is certainly no chance for alternating weathering which should be able to form black soil. Perhaps there is a certain amount of doline formation although it is not very distinct. On

13. J. J. Van Roon, Jaarb. Topogr. Dienst N. I., XI (1915), p. 247.

the highest plateau are a couple of depressions where water collects.

According to Brouwer[14] the west northwest point of Bali (X), Mt. Prapatagoeng, consists of "recently elevated reef limestone"; Van Roon[15] considers it "not improbable that Mt. Prapatagoeng is an extinct crater."

Perhaps it is a volcanic core with a mantle of limestone. The mountain has been only seldom visited by researchers, and still less investigated pedologically. In any case the surface soil is without doubt rich in volcanic ash.

Evaluation and Utilization of the Soil

From the viewpoint of agricultural evaluation the plain of south Bali is without doubt the best of the whole island. Physically the soil is good, but it is still so juvenile that in general it is very pervious and for lowland rice culture needs quite a good deal of water. It is particularly in this land of not overly much rain that the water is apt to fall to a minimum. This has forced the inhabitants to make great efforts to establish means of carefully conserving the water, and it is thus not accidental that they have developed their methods of irrigation to such a relatively high level.

Adequate irrigation water signifies a certainty of harvest. Yet the irrigation in a land as this which is analogous to the great stretches of the Principalities and the Kloet deposits, etc. (of Java), places particular requirements upon the land. If one asks himself as to what can be lacking in such a beautiful land as this?--then it may be recalled that, in addition to water, organic matter, nitrogen, and phosphoric acid can also be necessary. The very juvenile soil types of the tracts I and II of the sketch map (Fig. 58, page 200) have perhaps never, certainly not in the last few centuries, had the opportunity to cover themselves with heavy forest (see Fig. 62, page 206) and to form a strongly humous soil. There is every climatological reason for one to believe that the lower the elevation, the less humus there is. And then it must be kept in mind that the lower the elevation, the more population there is and apparently always has been. So also for this reason there has not been much opportunity for an increase of humus. Hence humus may be at a minimum, as well as water.

As was already recorded on page 196, it is remarkable that the rock magma apparently sometimes had a nitrogen content not to be ignored. After the eruptions, this nitrogen was liberated in the form of ammonia or ammonium chloride, but in what degree that is the case, is not known. The rock analyses[16] give the amount of S and Cl, but not of N. Nor as far as I know have there ever been carried out definite investigations of the ammonia N content of water flowing from very recent efflatas. And if there have been determinations of ammonia N in the irrigation water from localities of this sort, there has never been a differentiation of this ammonia-N into N from endogenous origin (from the magma) and from exogenous origin (coming from the atmosphere, whether via the mountain vegetation or not). For simplicity, that content is always ascribed to the latter origin. Nor do the published investigations made in the course of the provision of drinking water[17] deal with waters which are definitely known to originate exclusively from fresh ash. At least nothing is mentioned about this. Perhaps in the future there will be an opportunity to carry out researches in the direction referred to here. Meanwhile in practice it is quite apparent that the nitrogen content of the Bali soils in general is rather on the lower than on the higher side.[18]

Hence green manuring, which increases both the humus and the nitrogen content of the soil, is therefore the

14. H. A. Brouwer, Jaarb. Mijnw. N. O. I., 44 (1915), Verh. Dl., II.--
15. Van Roon, l.c., p. 229.
16. See page 197.
17. Jaarversl. Proefst. v. Waterzuiv. Manggarai, 1929 and following years.
18. Dept. L. N. H., Versl. Afd. Lb. (1928), p. 402: in the unirrigated lands on the slopes of the Brantan, on the Batoer complex and on Mt. Agoeng in South Bali, judged according to the color and in the stand of the "gogo," a deficiency in nitrogen is evident.

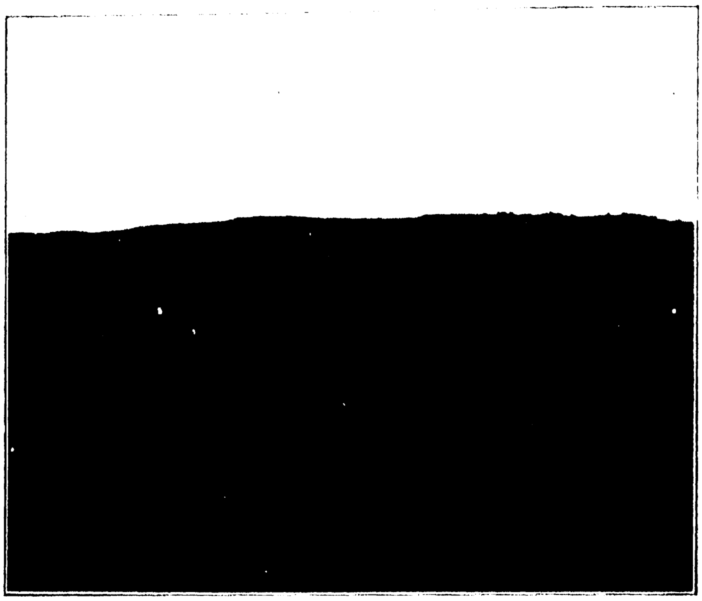

Photo by Straub

Fig. 62. Between Banli and Kintamani, Central Bali. The treeless "high dry soil," from which every second year a poor upland rice or sweet potato harvest is obtained. After green manuring once, the increase of production is 50 to 100 %. (Straub)

means for increasing the fertility of these juvenile, mineral soil types of Bali. It is interesting in this connection that J. Straub, the agricultural adviser, has stated[19] that the Balinese by the empirical route have already since times immemorial practiced green manuring. Not alone on lowland rice fields, but also on the unirrigable upland fields where they raise maize, they plant as the intercrop Cajanas cajan (pigeon pea) (see Fig. 63, page 207). Perhaps one will now say that they do this for the "peas" which are used as a protein-containing food. This might hold good for the first harvest, although the bean straw is then worked under. But especially in tract I of the little sketch map, immediately a second planting of Cajanus is made. The entire plants, seeds and all, or expressed better, before the ripening of the seeds, are worked into the soil. According to the statement of the motives of the Balinese farmers, this is necessary in order to obtain a decent crop of maize.

However, as is often the case with empirically found rules without adequate conception of the reason--in practice divergencies frequently occur. Especially, if the rice and maize harvest has been small, whether because of the (nitrogen) poverty of the soil, or from meteorological or other influences, many sweet potatoes are planted on Bali, a food-stuff rich in starch but poor in protein. But the Balinese can make out with this, in contrast with the Javan Mohammedans, since the former secure protein in their pork. Hence peanuts are not so necessary for the Balinese as a food. In either case,

19. In verbal communications to the author, later amplified by very valuable written observations and photographs with legends, some of which have been included in this book.

Photo by Mohr

Fig. 63. Higher part of South Bali.--Cajanus cajan, the green manure of the Balinese inhabitants.

although the Balinese farmer does not yet today adequately realize the significance of green manuring, the agricultural extension service which is based upon Occidental foundations does know it, and acts accordingly.[20]

It is also conceivable, especially after what was said above (page 203) regarding landslides, etc., that green manuring is more necessary higher up in tract I (see Fig. 62, page 206 and Fig. 64, page 208), where deep ravines cut relatively small ridges. There the soil is the most juvenile and raw, and in the surface soil there is the most need of organic matter and nitrogen. On these lands, for the most part unirrigable, there is raised much maize in alternation with green manures, but also vegetables, such as kinds of terrong.

Higher, in the forested parts of the mountains, where a quite humous surface soil can form, the natives plant much coffee. This is done under a leguminous shade tree, namely dadap (Erythrina sp.) (see Figs. 65-66, pages 208-209). This crop does excellently, even though it is not given the care which an Occidental[21] would consider necessary.

On the lower northern slopes, where a sharp dry monsoon prevails, kapok culture is possible, because of the interplanting of the green manure crop Crotalaria.

If the question as to whether in the near future commercial fertilizers will play an important role in Balinese agriculture is raised, the figures of the rock analyses on page 197 should be examined, with particular reference to phosphoric acid. It is unusual and striking that such basic rocks show such small quantities

20. Versl. Afd. Landb., 1928, p. 403. The green manure with which the best success has been obtained is Crotalaria anagyroides (see Fig. 64).

21. See: G. J. Vink, De koffiecultuur der Baliërs, Landbouw V, (1929), p. 1.

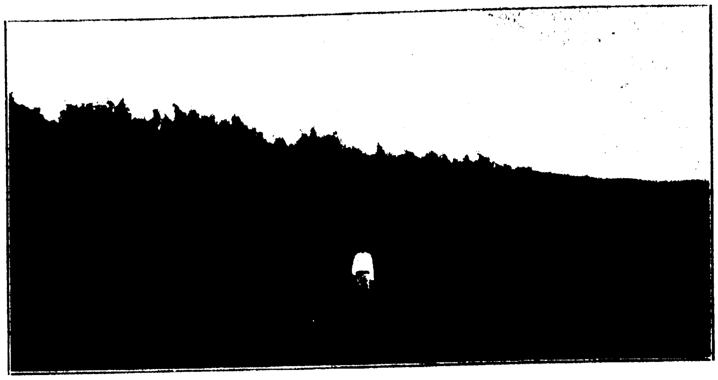

Photo by Straub

Fig. 64. Bali--Luxuriant development of the green manure Crotalaria anagyroides on the "high, dry soils."

Photo by Straub

Fig. 65. Young native coffee under dadap (Erythrina variegata L.) on very juvenile efflata soil, without any protection against erosion. Central Bali.

of phosphoric acid. In fact one lava does not contain any at all, while in three lavas and an ash only traces are present.

But two things indicate a condition entirely different. C. H. van Harreveld-Lako and O. Arrhenius[22] give, in addition to a description of the soil samples from Bali investigated by them, also analytical figures showing the amounts of phosphoric acid (Table 58, page 210). For the greater part from the standpoint of agriculture the soils cannot be classified otherwise than high to very high.[23]

Entirely in agreement with this table (Table 58, page 210), in the text they state:[24]

> "In the low plains along the coast the soil consists of gray and brownish gray volcanic ash, which is rich in phosphoric acid (and potash) and has a very desirable texture..... On the slopes of the volcanoes the soil consists likewise of the same young volcanic ash as in the plains. In some places however the recent ash mantle is no longer present..... It has been washed off and there remains exposed a moderately weathered, orange brown more cohesive soil, which just as is the case with similar sorts of soil on Java, possesses but little phosphoric acid soluble in citric acid. (Nos. 566, 571, 576)."

22. C. H. van Harreveld-Lako and O. Arrhenius, Grondonderz. van de Buitenbez., Arch. Suik. Ind. Ned.-Indië, (Soerabaia, 1927), Dl. III, p. 709-826; Meded. Proefst. Java-Suik. Ind., No. 18.
23. L. c., p. 719.
24. L. c., p. 718.

Photo by Mohr

Fig. 66. Luxuriant arabica coffee under dadap (Erythrina variegata L.) near the Brantan lake, Central Bali. Soil: humous, juvenile brown lixivium: V.b.I.--Wa.NN.ae.2.

Photo by J. Straub

Fig. 67. Good, older garden of native coffee (C. arabica) on humous, brown lixivium: V.b.I.--Wa.NN.ae.2. Central Bali, near the Brantan lake.

Table 58

Serial No.	Region on the sketch of Kemmerling (See Fig. 58, p. 200)	Location on Bali and Description		Surface soil or subsoil	P_2O_5 in %	
					Soluble in HCl	Soluble in citric acid
556	VI	Northern coastal plain, a little above the sea. Tedjakoela. Rice paddy.	Gray ash soil	Surface	0.082	0.055
557	VI	Northern coastal plain, a little above the sea. Tedjakoela. Rice paddy.	Grayish ash soil	Surface	0.085	0.056
558	VI	Northern coastal plain, a little above the sea. Djinengdalem, 1st class rice paddy.	Gray ash soil	Surface	0.063	0.038
559	VI	Northern coastal plain, a little above the sea, Djinengdalem, more westerly.	Grayish ash soil	Surface	0.074	0.041
560	VI	Northern coastal plain, a little above the sea, Boeboenan.	Yellowish gray ash soil	Surface	0.061	0.035
563	I	Along the road: north coast near Kintamani, 385 m. elevation south from 557/558.	Yellowish brown sandy ash soil	Surface	0.089	0.047
565	I	Along the road: north coast near Kintamani, 385 m. elevation. below 563.	Light orange brown clods	5 m. deep	0.058	0.027
561	V	Along the road: Boeboenan toward Moendoek, higher than 560. Rice paddy.	Gray ash soil	Surface	0.046	0.022
562	V	Along the road: Boeboenan toward Moendoek, farther. Higher than 561. Non-irrigable.	Chocolate brown	Surface	0.128	0.019
566	V	Along the road: Majong-Moendoek, Road cut. Older lixivium.	Dark orange brown clods	Subsoil	0.016	0.003
567	II	Plain, South Bali by Kloengkoeng: 1st class rice paddy.	Yellowish gray ash soil	Surface	0.068	0.043
568	II	Plain, South Bali, south from Gianjar: 2nd class rice paddy.	Light gray ash soil	Surface	0.048	0.029

Table 58 (Continued)

Serial No.	Region on the sketch of Kemmerling (See Fig. 58, p. 200)	Location on Bali and Description		Surface soil or subsoil	P_2O_5 in %	
					Soluble in HCl	Soluble in citric acid
569	II	Plain, South Bali, at the Market; 2nd class rice paddy	Yellowish gray ash soil	Surface	0.071	0.044
570	II	Northern part of the plain of south Bali by Mengwi; rice paddy.	Hard, light gray ash soil	Surface	0.042	0.022
573	I	South slope Bratan, by Batoeriti. Rice paddy	Grayish yellow ash soil	Surface	0.104	0.055
574	I	South slope Bratan by Batoeriti. Non-irrigable.	Orange brown soil	Surface	0.051	0.025
575	I	South slope Bratan, by Batoeriti. Deposits of the river Soengi.	Grayish brown sandy soil	Surface	0.054	0.027
576	V	South slope Bratan, by Batoeriti. Non-irrigable maize field; eroded.	Orange brown little clods	Surface	0.015	0.002
577	IV	Older lixivium from older volcanic conglomerate near Bangli.	Reddish brown light clay	Surface	0.027	0.002
2610	VII	Western plain of Djembrana Tjandikoesoema.	Light brown fine sandy loam soil 0 - 33	Surface	0.095	0.044
2611	VII	Western plain of Djembrana Tjandikoesoema.	Light brown clods 35 - 100	Subsoil	0.122	0.032
902	X	Prapatagoeng. Sea level. Forest on coral lime.	Sandy, dark brown	Surface	0.084	0.058
909	X	Prapatagoeng. On the slope: 60 m. elevation. Coral sand more than 4 m. deep.	Sandy, brownish gray	Surface	0.068	0.019
907	X	Prapatagoeng. On the top: 310 m., lying on layered tuff.	Sandy, dark brownish gray	Surface	0.064	0.051
577	IX	Tafelhoek. Southwest from Djimbaran on limestone. 30 - 40 m. above the sea.	Shallow, dark brown, dry	Surface	0.059	0.015

Hydrochloric acid never extracts all the phosphoric acid present. In the soil there is therefore more than is shown in the above figures which run up to 0.128%, quite outside of the designation "traces" (less than 0.1%). Hence another analysis of the P_2O_5 figures of the Bali rocks seems desirable, since for similar rocks from elsewhere figures of 1/4 - 1/2%, seldom under 0.1%, but even above 1 1/2% have been found.

The quantities of P in Table 58, pages 210-11, are quite in line with similar analyses of Java soils, particularly of those occurring in the eastern corner, which produce equally high rice yields as Bali. The yield of rice is indeed very high,[25] and this practical result confirms the figures of the Experiment Station for the Java Sugar Industry. In the above quotation it is also correctly interpreted.

Only on the brownish red lixivium soils, already weathered beyond the virile stage, will there be any need of P fertilizers in the near future. These soils occur in the tracts III (south), IV and V, where the rejuvenating ash had been eroded off before it had been incorporated with the soil beneath.

As to the quantities of potassium reported in the publication referred to, the following figures (Table 59) are recorded:

Table 59

Serial Nos.	K_2O Soluble in hydrochloric acid %	K_2O Soluble in citric acid %	Description
558	0.105	0.057	Ash soil
561	0.096	0.052	Ash soil
566	0.090	0.050	Older lixivium
569	0.104	0.037	Ash soil
570	0.073	0.035	Ash soil
571	0.134	0.049	Older lixivium

These K values are also high. It is worthy of note that the older lixivia often show even still higher amounts of potassium than the younger ash soils. It is not impossible that from the ash which without doubt must also have fallen upon the lixivia, before it eroded off, the potash had already been leached out, moved downward, and was fixed absorptively in the more weathered, colloidally rich lixivia. But it is also plausible that during the weathering little K and P were washed out, yet the K was held in such a way that it remained extractable by acids, while the P was so fixed (for example combined with Ti), that it did not go into solution during the usual extraction by acids.

However that be--deficiency of potassium certainly does not occur here, although the rocks and the ash have but 1/2% to 1% of it. Hence fertilization with K is still less an urgent question on Bali than fertilization with phosphorus. For the time being everything comes down to nitrogen, organic matter, and water; hence the attention to green manuring and irrigation.

LOMBOK

Soil-Forming Rocks

Thanks to the exhaustive geological research of van Heek[26] the nature of the soil forming rocks of Lombok is for the greater part quite well known. That there may be uncertainties as to the geological age of some formations is for us of less importance.

As in Bali, the young volcanic rocks are also the most important. Nevertheless there is an important difference between the two islands, namely in the relative positions of more acid and more basic members of the group.

On Bali, as for example in the environs of Kintamani it has been clearly observed that during an initial eruption period of Batoer, the more acid pumice stone was spread out in great masses over the whole land. Later in the eruption period, basaltic extrusions were predominant, now and then alternating with or accompanied by ash eruptions of relatively

25. F. A. Liefrinck, T. schr. Binn. Best., V (1891), p. 14.
26. J. G. B. van Heek, Bijdr. t/d geol. kennis v/h eil. Lombok, enz., Jb. Mijnw., 38 (1909), Wet. Ged. (1910), p. 3-80.

basic material. But on Lombok the basaltic extrusions took place much earlier (perhaps during the same time that on Bali Mt. Agoeng was active), and the main ash mass of the Rindjani was somewhat more acid, followed by still more acid ash and especially by pumice stone.

As can be observed in the deeper ravines, the mantle of breccia lies on solid basalt. The breccia itself is sometimes already more or less hardened, sometimes however very loose, consisting of volcanic ejecta--blocks of rock of very diverse dimensions in a matrix of fine rock fragments. In layers of very differing thickness on this breccia lies the pumice stone material thrown out during the most recent eruptions. Van Heek continues:[27] "This breccia is composed of more or less porous basalt and particularly of pyroxene andesite containing hypersthene"; thus clearly more basic.

"Where the pumice stone layers occur in primary bedding, they consist of two layers of gravel (scoria) of different grain size, separated by a fine more or less loamy pumice sandstone layer, under which occurs a thin hard rusty brown crust."[28] Presumably the explanation is this: the included finer layer will 1st, because of its fineness weather earlier, and through this will become a pale water-holding, almost impervious layer. Weathering clay from pumice stone is never more than only slightly ferruginous, thus more plastic, hence more impervious. 2nd from the denser layer water will not be able to go downward into the coarser layer of gravel or only with much difficulty; the water remains suspended. But in the gravel there is air. Hence if there does penetrate downward from above a solution with iron, for example, in the ferrous form, then on the bounding plane this iron must precipitate and forms an ore crust.

Somewhat further on we read[29] how also in the lower parts of the terrain, where the pumice stone material is washed together to a considerable depth, the pumice stone layers alternate with thin and frequently extremely heavy clay layers which are completely impervious to water. Where the terrain is favorable for springs, beautifully clear water comes to the surface above this impervious layer.

Especially, however, in the triangle facing the sea, Alas strait, and enclosed by the lines joining Ash Dalem in the northeast, Koete Radja in the northwest, and the Rambang airport in the south (see region II in the sketch map, Fig. 68, page 214) the accumulation of pumice stone by washing in has been so great that here the pumice stone is 20 m. deep and more. It is this which gives that region a very peculiar character, and to which the climate very certainly contributes.

The above applies chiefly to the central, dominating Rindjani mountainous country and to its foot, developed broadly toward the south (Region I). There are also still three other mountainous regions to be discussed.

In the west lies III, a region of some older mountains, consisting of pyroxene andesites and amphibole andesites, without basalt.--Southeast from there and hence west from Rindjani, stands Mt. Poenikan a volcano at present dormant. Although foundations of this mountain may be basalt, its crown and mantle consist of ordinary pyroxene andesite.

In the northeast of the island in Region (IV) stands Nangi, also an inactive volcano, with two craters the floors of which at present are tranquil plains growing irrigated rice. A few prosperous villages are along the edge, built on a lava stream. The Nangi also appears to have been begun with basalt, and afterwards to have completed its building up with andesites.

In the south of Lombok across the whole breadth of the island lies an extensive mountainous region (Region V). In a north and south direction, directly south of Mataram, it is the broadest. There one comes across the Maredje mountains, old volcanoes which consist not only of ordinary pyroxene andesites, but also of hornblende andesites and quartzitic dacites. Breccias of all these rocks also occur. Van Heek believed the hypersthene andesites occurring on the separate mountains to be

27. L. c., p. 54.
28. L. c., p. 58.
29. L. c., p. 60.

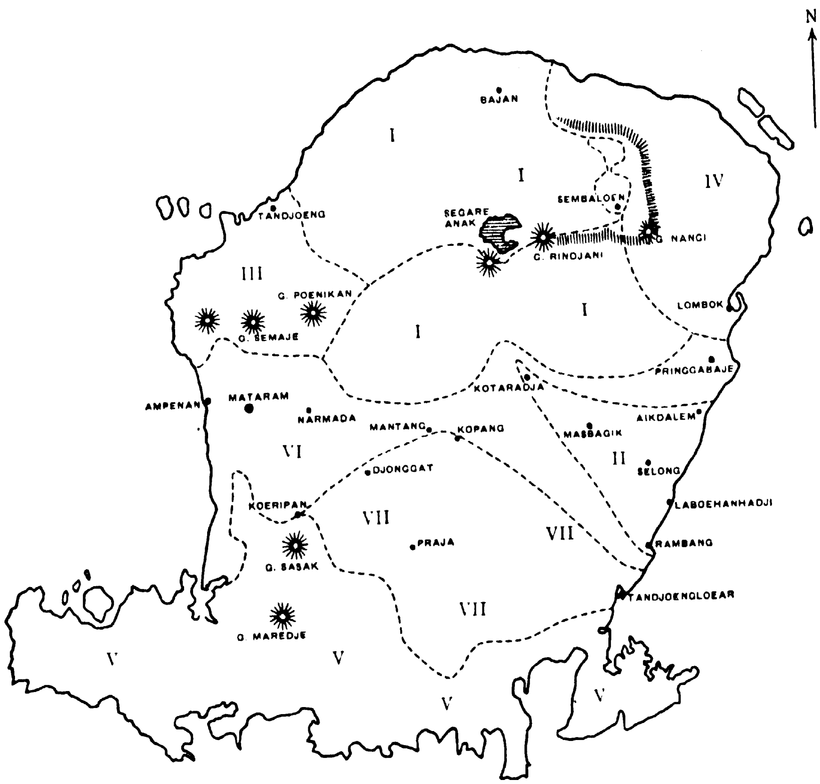

Fig. 68. Map of Lombok Island showing the principal geologic and geographic regions.

somewhat younger. At the same time at different places on these mountains large bodies of limestone occur after the manner of those of Tafelhoek on Bali.

None of these southern mountains are high. Hence they have not contributed to the formation of the plain lying between north and south Lombok, the plain which extends from Ampenan via Praja to Tandjoengloewar.

No analyses of rocks of Lombok have been found in the literature.

Climate

The climate of the different parts of the island differs very greatly indeed. But in general, at any rate in the inhabited portions, as compared with the rest of the Netherlands Indies, the climate is rather dry. Not a single rainfall station has a yearly average exceeding 2 m. By analogy with Bali and East Java, however, one may quite safely conclude that on the uninhabited southern, western, and northwestern slopes of the high mountains places do occur where, in connection with the rising air currents during one or the other of the monsoons, more rain does fall. Van Heek[30] even says: "In the mountains, days without rain are infrequent." In sharp contrast to that are the following rainfall figures (Table 60, page 215) for periods varying from a minimum of 14 years (Kopang) to a maximum of 36 years (Ampenan):

30. L. c., p. 67.

Table 60

DISTRIBUTION OF RAINFALL DURING THE YEAR ON LOMBOK[1]

Place	Location	Elevation in meters	No. of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Ampenan	West	2	36	88	195	170	180	95	71	59	41	27	37	120	144	254	1394	6	4
Mataram	West	15	27	94	243	240	234	116	91	79	41	51	64	186	220	306	1871	7	2
Kopang	Central	355	14	85	248	224	197	81	52	33	33	60	31	117	193	274	1543	6	5
Praja	Central	101	17	97	266	231	221	140	109	48	30	36	27	89	162	336	1696	7	4
Tdg. loewar	Southeast	2	16	65	194	140	127	32	30	16	17	12	6	30	48	178	830	4	8
Selong	Southeast	148	35	65	189	185	136	57	27	21	17	14	9	23	67	173	919	4	7
Lombok	Northeast	2	16	65	162	119	99	66	36	42	16	7	7	13	54	120	714	3	7
Bajan	North	200	16	64	366	363	242	76	44	22	11	7	7	15	58	228	1440	4	7
Tandjoeng	Northwest	10	16	74	313	380	215	75	54	31	11	7	17	42	77	205	1427	4	6

1. Rainfall figures taken from Verh. No. 24 of the Kon. Magn. Meteor. Obs., Batavia, p. 210, up to 1928 inclusive and corrected with the data for 1929 and 1930. Figures for later years were not yet published (1934).

The great difference between rainy season and dry season is clear. The most striking difference is perhaps at Bajan, where 5/6 of the total rainfall occurs in 4 months, while in the dry half-year but 1/13 of it falls. All places, however, show a dry season with months of less than 60 mm. The weakest dry period with an average minimum of 41 mm. is at Mataram. But that however does not say that a long and very severe dry season sometimes does not occur; while other years have a few heavy showers in the middle of the dry months. The possibility for a pause in the water movement in the soil is hence generally more or less present, and where the soil permits it, even for a reversal of the sinking movement into one of ascent. Certainly this is clearest in East Lombok where there are 6 continuously dry months. In west Lombok a reversal of soil water movement is not to be expected. Apart from that, however, as already frequently argued, the nature of the soil is at least of equally great significance as is the climate for the ascent of water in the soil.

Since there are no data of temperature observations on Lombok, we are dependent upon personal observations, which are really estimations. At low elevations the temperature varies within the usual limits for the Indies. On Mount Rindjani (3,700 m.), however, it falls to within a few degrees centigrade of the snow line, and even if volcanic activity might be permanently suspended in the future, no forest could grow at the summit. Even elfin-wood would not grow; at most some herbs would be present.

The air is very dry in the east monsoon, especially in eastern and northern Lombok. Nevertheless evaporation can never be more than the available water. As a consequence in the dry months all strongly pervious soils (coarse ash and pumice stone) which have only an unimportant power of capillary ascent, and a ground water level deeper than one meter below the surface, can hardly evaporate more water than the rainfall in those months. It is likely that in the 4 rainy months the evaporation from the soils is significantly greater than in the 6 to 8 dry months.

Now what name should we give to the climate of, for example, the lower tracts of East and North Lombok?--It is not humid, it is also not arid, nor is it intermediate. It is simply periodically alternating humid and arid, sometimes without even a short transition period and sometimes with one. Whenever there is an opportunity the humid climate, as well as the dry one, places its stamp upon such natural phenomena as the weathering and the vegetation.

As regards the vegetation in the tracts referred to, trees which cannot withstand a dry period of a half year or more must disappear unless the provision of water is made up from elsewhere. Forest along the rivers is thus possible, while somewhat farther from the streams smaller groups of trees exist. Still farther away

single trees somewhat apart from each other (park landscape), are present, so that they do not take from each other the last of the soil moisture. And finally a treeless plain exists, a savanna, with grass which withers in the dry season, besides a few xerophytes (Euphorbias, Opuntias, etc.). Of the grasses it is especially Andropogon contorsum, which characterizes this climatic form.

Ways in Which Weathering Occurs and Resulting Soil Types

Because the east and west slopes of the Rindjani abutt against Mts. Nangi and Poenikan, for all of North Lombok to the north of the line connecting Tandjoeng and Lombok there can quite well be accepted similar ways of weathering of similar rocks. Moreover the repeated eruptions of the Rindjani have made this whole region still more uniform as a result of the equal covering by young andesitic ash. As compared with the northern half of Pringgabaia, the Bajan district has a distinctly stronger rainy monsoon, with intermittent leaching of basic volcanic, porous material, which in the course of a long time will form reddish brown lixivium,--as yet the soil is in only the first very young stage. In due course this district can, especially higher up against the mountains, carry quite good forest if new eruptions of ash do not destroy everything, so that a start has to be made all over again. There is practically no coastal plain, nor will one develop quickly because the sea immediately to the north of Lombok is very deep.

North Pringgabaia, however does have some small plains along the coast. These plains are rich in dissolved and soluble soil constituents, and if they can be irrigated they will be productive. Mt. Nangi is somewhat older. As a consequence, in the rainy season, the small streams bring down somewhat more weathered silt. If this settles out on the lower land, there is every chance that here as a result of the alternating weathering a soil first more gray, and becoming black ultimately will develop. Such a soil will hold more water in the beginning of the dry season. Higher up against the east slope of the Nangi, if forest can begin to maintain itself, the soil must be somewhat richer in humus. But the low ridges are now savannas poor in trees, with a grayish black surface soil and much unweathered stony material.

In the very wide double crater of the Nangi are now a couple of plains, which receive adequate water from the west monsoon--the winds rising against the steep inner wall in the east, drop much rain there. Here, at 1,200 m. elevation, brown lixivium is forming. This soil has a dark brownish black humous surface horizon under a well-closed-in forest.

On the southern slopes of the volcanoes rain falls even in the east monsoon. As a consequence, due to the porous, sloping terrain there, the weathering in progress is in the beginning stages of a reddish brown lixivium. At the same time the erosion prevents the accumulation of weathered soil, so that the stage of juvenile, even fresh soil material can still persist for a long time. Where however the pumice stone, mentioned in the description of the rocks, predominates, there is formed a less reddish brown, a more yellow to pale yellow weathering product. It is more plastic, cohesive and resistant against erosion. Then there is that brownish yellow soil with (under forest) sometimes an intensely dark very thin humous surface soil which is sharply differentiated from the horizon just beneath it. If the forest on such a soil is cut off very rapidly, (in one or a few years) the brownish black layer will be washed away.

Lower, in the districts Masbagik, South Pringgabaia and Parang, the pumice stone layers are so thick that there is still very little soil formation to be noted. In the course of a long time, however, here also the intense black soil characteristic of the alternating weathering must develop. Along the rivers, in the ravines which are being continually widened by the meandering of the streams, an allochthonous soil develops from weathered and unweathered fine pumice stone material. This gives the soil a light color, besides darker material of andesitic nature coming from the slightly cemented stone and ash cut through by the rivers. These latter materials, while somewhat older than the pumice stone,

are still almost fresh.

Now before the large plain from Ampenan to Tandjoengloewar is taken up for consideration, just a few words about the remaining mountainous regions. In the Tandjoeng district, on the northern slopes of the older mountains already mentioned, the reddish brown lixivium of the intermittent weathering has reached a further stage than in Bajan. But here also, now and then rejuvenating ash has been scattered over the land. As to mineral fertility there is hence no lack; nice forest ought to be standing on it, except that in the coastal plains the inhabitants have need of wood and so have cut down much forest. The consequence is that these lands are also kaiñgined, and not much humous surface soil is to be seen on the present-day cultivated fields. The eroded soil lies on the plains or has been carried on into the sea.

The southern mountains are scantily wooded, without roads, and seldom visited. In the literature observations relating to the soil are scarce. Van Heek on an expedition toward the summit of Mt. Maredje[31] found "a thick, dark colored, weathering soil, heavily covered with vegetation, especially toward the top." Apparently it was a quite humous brown lixivium, originating from andesite through intermittent weathering. Here and there on the limestone lies also a thick layer of weathering soil, carrying a vegetation among which even bamboo occurs, which should indicate a mixing of volcanic ash or other volcanic material. The limestone itself however seems not to be tuffaceious. Hence these substances mixed in the weathering soil must be of younger, Quaternary, date.

* * * * *

The most important and also pedologically most interesting part of Lombok is the plain which runs from the west to the east right through the middle of the island. It consists of two parts, separated by a line from Mantang across Djonggat situated on the most southwesterly toe of Mt. Rindjani's foot, towards Koeripan, located on the northern edge of Mt. Sasak, which belongs to the Southern Mountain Range.

The portion of the plain (VI) west from that line, the plain of Tjakranegara, which slopes upward from the northwest toward the east and southeast some 50 meters, is entirely a product of the volcanoes lying to the northeast. The soil consists of the fine and somewhat coarser ash, mainly Rindjani ash. Only in the most northwestern part have the rivers coming from the Poenikan and Mt. Semajo mixed with the soil other but similar kinds of andesitic material. Properly speaking the material is still too fresh to be called allochthonous soil. Yet I use this term here because without doubt from higher regions eroded surface soil, and with it weathering minerals and even humus are brought in, and play their part in determining the character of this soil. Intermittent leaching is the weathering form at the present time. This is because, by nature, the soil is still so porous. Now, however, that the greatest part of the plain has been converted into paddies, and will remain so, within the immediate future amphibian weathering will occur. In fact the commencement of this type of weathering is already observable--here and there can be seen some reddish brown threads of iron oxide on dry gray clods of ash loam.

The lower foot slopes of the volcanoes merge very gradually into the plain. The Southern mountains, on the contrary, rise up very sharply out of it. This indicates at a glance from which direction the material has come which fills up the plain. In this the Southern mountains have had just a little a part as, for example, on Java between Blitar and Toeloeng Agoeng the Southern mountains have had on the plain which lies there; there everything came from the Kloet volcano.

That portion of the plain (VII) east from the above-mentioned constriction near Koeripan, called by Van Heek[32] the plain of Batoedjai, appears to have an entirely different character. The soil consists of "a relatively thin layer locally

31. L. c., p. 15.
32. L. c., pp. 65 and 70.

only a few meters thick. It is the so-called tanah malit, a black kind of soil, which in the moist condition forms a heavy clay, and when well dried cracks into clods as hard as stone. Meanwhile it is worth mentioning that it is the soil's plasticity in its moist condition which lends to this otherwise very poor soil its suitability for preventing the rapid sinking away into the subsoil of the rain water which in this region is so precious for the farmer." From this description of Van Heek it is immediately apparent that "tanah malit" is a soil type apparently similar to the black soil so frequently observed in the dry tracts of Java, and there often called "rantja minjak." This soil also in some respects resembles the western North American "adobe soil."

Van Heek speaks of a "relatively thin layer." If it is however "locally only a few meters thick," he must have meant to say that this layer is only locally as much as a few meters thick and everywhere else is thinner.

Regarding the occurrence of calcium carbonate concretions nothing is said by Van Heek. He does say, however, that "the tanah malit does not possess particles of pumice stone or only sporadically so." It is not impossible that the presence of lime concretions was overlooked. At that time (1909) in the Netherlands Indies lime concretions as autochthonous soil formations were but very little known. And according to the following statements[33] pumice stone remains are also improbable. "Upon sedimentation this kind of soil leaves quite a good deal of sand, which for the most part consists of glistening fragments of feldspar. Further research brought to light that besides plagioclase, fresh hypersthene and some augite and ore occur, while olivine is lacking. From this composition it would appear that the 'tanah malit' was formed only after the eruptions of basalt and olivine-containing pyroxene-andesite had given way to eruptions of hypersthene-containing augite andesite."

It is possible that this soil type has originated from andesitic material. This is why under the "tanah malit" is found especially breccia or conglomerate with much rock which is recognized as pyroxene andesite or basalt. Thus the "tanah malit" cannot be older than Quaternary; but it is old in the Quaternary. It had already then begun to form from the relatively thin cover of loose volcanic material laid down on the Tertiary hilly ridges which run from the south toward the north. And the formation of this soil has been continuous, on down to the present day.

The climate has certainly also contributed to the formation of this soil. The long dry season, especially in the east, contrasts sharply with the much weaker east monsoon in the plain of Tjakranegara. One need only compare the rainfall figures of Mataram and Tandjongloewar. Besides it is in no sense excluded that in the plain of Tjakranegara in the course of a long time more black "tanah malit" will form if the volcanoes remain quiet long enough and the rivers do not spread any fresh ash out over the land. But under regular irrigation such soil development cannot progress very far.

Evaluation and Utilization of the Soils

After all that has been said above about the kinds of soils on Lombok and their nature, the conclusion is very simple. Where there is adequate water, the fertility of the soils is generally more than adequate. The best soil of all, and therefore also the center of concentration of the population in the west is in the plain of Tjakranegara (VI). Regarding this plain Van Heek wrote:[34] "One glance at the map is enough in order to see that especially the plain of Tjakranegara is extraordinarily richly blessed with the life-bringing irrigation water. Approximately 1/4 of the water falling in the mountains flows into this relatively small plain, so that the plain is traversed by a whole lot of parallel flowing streams. The plain has these streams providing the water so necessary for the rice culture and also the preeminently valuable material which the streams have carried in. Moreover where

33. L. c., p. 71.
34. L. c., p. 67.

the irrigation, laid out by the Balinese who know how to do it, assists nature, it is no wonder that this small plain gives excellent yields."

Because of the condition which has prevailed from time immemorial, viz. that the streams on the south side of the volcanoes go partly to the west and partly to the east, the center of the plain receives the least water. The land very likely had a saddle in the center as long ago as Tertiary times, a saddle which lay higher than the land to the west and east of it. While the extensive eastern pumice stone plain (II) (see above, page 215) does receive a good deal of water, it is of not much use on the uplands. Only the small valleys in the bottoms of the ravines are adequately provided with water, so that the rice cultivation is concentrated there. While on the pumice stone plateau almost desert-like drought prevails.

Thus in the west there is an excess of water, in the center there is a scarcity, even poverty; while in the east, excess and lack are both present. As to the deficiencies there is not much to be done. Little by little the streams will continue to abrade their valleys broader and broader until the little ridges are consumed and the entire district of Parang becomes one fertile plain. What a beautiful problem however is there for the irrigation engineer in the center of Lombok. Namely, to withdraw and lead off a part of the excess water, which now flows toward the west and the east, in such a way as to give it to Central Lombok (Djonggat and Kopang), and to do this without depriving the west and east of water. It is no wonder that here the Irrigation Service in cooperation with the Agricultural Extension Service is devoting all its attention to it. Perhaps in 25 years one may see in the districts of Batoeklian and Masbagik a whole series or chain of siphons, so that the "tanah malit" in the south can be rejuvenated with volcanic silt. It has been a long time since the covering of ash fell, which has now become the black earth.

Yet water is not everything in this agricultural matter. There is an abundance of mineral plant food substances, at least in the east and especially in the west. But just as in the young ash tracts of Java and Bali, there will sooner be a lack of nitrogen and since there are also inadequate colloidal weathering minerals present in the ground, there is at the same time a lack of humus. Hence the need of green manuring or at least of alternation of rice and maize with profitable legumes such as varieties of peanuts.

In the large plain VII to the east of Koeripan, in the center of which Praja is located, with a few exceptions, the paddies upon "tanah malit" are dependent upon rain. It is a pity that for Lombok there are still not available figures of yields (experimental cuttings) in relation to tillage[35] for a series of years, otherwise there would be certain instructive conclusions to be drawn. Also soil analyses from Lombok are thus far lacking in the literature. Therefore considerations remain very speculative, for we cannot get very far merely on the basis of observations.

So, judging by the heavy rice yields of West Lombok, one might quite easily conclude that no phosphorus deficiency can prevail. In the plain south of Praja the yields are smaller, a result often to be ascribed directly to lack of water, but, the possibility is still not excluded that the "tanah malit" may be deficient in available phosphorus. Only plot tests supplemented by analyses will be able to settle this.

Also as to the pumice stone region we are in no sense certain whether or not there is a P deficiency, but the thorough mixing together in the river valleys of more basic andesitic material greatly reduces the likelihood of this.

Regarding the soil of the Southern Mountain Range it is very hazardous if not almost inadmissible to say anything. Far too little is known about it. Drought will certainly be the principal hindrance to more inhabitants living there. Apart from that, pure limestone tracts, such as the southeastern peninsula of Ekas, are not very tempting. Even for teak such localities are not apt to come up to expectations. The Maredje Mountain range is apparently not quite so bad, but perhaps its fertility will be rapidly exhausted as soon as the

35. The Extension Service at Lombok has been established only since 1928.

forest is replaced by cultivation. Without a previous investigation of soil and climatic conditions, it is certainly not desirable to induce people to settle here.

Adjoining the plain of west Lombok, and immediately to the north of the latter the stretch running east and west promises much more. The bringing on of water into this already higher land for paddy is difficult; for this reason the inhabitants raise unirrigated upland crops. The Agricultural Extension Service advocates for this region, as well as for others farther east on the foot of the Rindjani, near Mantang, the raising of kapok and of course also urges rotation with green manures. Whether on the "tanah malit" soy beans are being raised, has not thus far been learned from the literature.

A point worthy of mention is that along the northwestern coast of Lombok is a region with a relatively heavy west monsoon and a very sharp east monsoon. It is notable that here the natives grow a hardy cotton, although with declining success.[36] For this region the Extension Service is now recommending a combination of kapok and green manures.

In conclusion, something should be stated about the cultivation of coffee in the higher mountains, above 1,000 m. elevation. Without doubt there are localities where C. arabica can be raised successfully, as for example in the neighborhood of the crater of Mt. Nangi where the soil is somewhat farther weathered and where in the forest, in connection with the elevation, the soil has already become fairly rich in humus. A careful search should be made for pieces of relatively flat land. From the beginning, good cultural practices should be insisted upon.

Taken all together, Lombok is an island with a great deal of above the average, very juvenile agricultural soil. The principal agricultural problem seems to be that of a satisfactory distribution of water for irrigation. Where this has been solved successfully, the climate with a strong dry season is an advantage rather than a disadvantage.

But water cannot be brought on to the Southern mountains. Hence here little agricultural development can be expected. Perhaps stock raising is the best activity for this region.

* * * * *

SOEMBAWA

Soil-Forming Rocks

The geology of Soembawa is even much less well known[37] than that of a number of other islands; even so there are to be recorded a few important facts of great significance for the soil of today.

In the first place may be mentioned the 1815 eruption of Mt. Tambora, which buried deep under ash not only the peninsula upon which the volcano lies, but also other large parts of the island. It was recorded by Zollinger[38] after the outburst that "the volcanic gravel layer at Samgar was over 3 ft. deep, at Bima 1.5 ft., on Soembawa 2 ft., in the west of the island and on Lombok still 1.5 ft., on Bali 1 ft., on Banjoewangi (Java) 3/4 ft. deep." This mighty eruption occurred in the first half of April, hence during the season of the east monsoon so that more of the ash went westward than eastward.

Hence whatever the soil and the parent rocks might have been before the eruption, by far the greater part of the soils of Soembawa have been intensively rejuvenated, and as far as their nature is concerned they have been strongly equalized in the direction of young volcanic soils. It is true that since that time more than a hundred years have elapsed, and therewith all sorts of things have changed. From the high points and convex slopes much ash and pumice stone have been eroded and blown away, accumulated in lower concave parts of the land, and have there commenced to weather. In this way bodies of the older land have again been exposed on the surface, and now weather in their own way but even so are always more or less influenced by thin, recent coverings of ash.

36. Afd. Lb. v/h Dept. L. N. H., Buitenzorg, Jaarverslag 1928, p. 324.
37. L. Rutten, Voordr. Geol. N. O. I. (1927), p. 653-656.
38. H. Zollinger, Versl. reis n. Bima en Soembawa, enz., Verh. Batav. Gen. K. en W., XXIII (1850), p. 150.

Table 61

Name.......	Dacite	Hornblende augite andesite	Hornblende augite andesite	Labrador andesite	"Laterite" crust	Leucite tephrite	Augite from
Origin.....	Sapeh	Tdg. Lok at Mapinbaai	Ndano	Gapit River	Overlying sample IX	Soromandi	XII
Analyzed by	Tillmans	Lindner	Lindner	Lindner	Lindner	Lindner	Lindner
Sample's own No. ...	I	IV	V	IX	X	XII	XIa
SiO_2	64.54	58.50	53.74	50.39	16.82	48.75	45.03
TiO_2	0.53	1.41	0.97	0.75	3.98	0.88	0.24
Al_2O_3	16.24	17.54	18.26	21.77	34.75	13.50	7.84
Fe_2O_3	5.88	3.32	6.21	3.51	19.17	11.21	7.97
FeO	0.11	2.56	3.00	5.23		4.83	5.88
MnO		0.08	0.08	0.10	0.14		0.23
MgO	1.17	2.93	2.69	3.55	0.80	3.73	9.61
CaO	5.17	7.04	8.06	10.61	0.44	9.51	19.76
Na_2O	3.71	3.48	3.58	1.63	0.26	2.96	1.91
K_2O	1.05	1.62	2.52	1.34	0.40	3.34	
H_2O + ...	1.99	1.23	0.60	0.06	20.74	0.33	0.87
P_2O_5		0.23	0.33	0.60	0.23	0.48	0.32
		0.10[1]	0.16[2]	0.41[2]	2.11[2]	0.48[1]	0.15[2]
	100.39	100.05	100.19	99.96	99.83	100.00	99.81
		[1]BaO	[2]moisture	[2]moisture	[2]moisture	[1]BaO	[2]moisture

In the second place it has become evident[39] that on Soembawa and the nearby small islands which belong with it, very different volcanic rocks occur. For example the rock samples, collected by Elbert were investigated petrographically by Rack, who was able to insert in the description a number of analyses. F. M. Hühnerwadel dealt with the samples of Pannekoek van Rheden in the same manner, however without analyses. The rocks are, it is true, for the greater part andesites, but also dacites as well as basalts were found. That the composition varies considerably will appear from Table 61. The fact, however, which needs special attention is that leucite rocks (-tephrite and -basanite) are found on Tambora and Soromandi, and also on the more westerly lying Sangenges. In how far these potassium-rich rocks were also involved in the ash eruptions, in other words, whether leucite or potassium-rich volcanic glass was spread out over the land with the ash, is even now still entirely unknown. Even yet no ash analyses from Soembawa are available. It would be interesting if leucite glass were found, as it would be

39. Besides the already briefly mentioned short synopsis by Rutten, the reader is referred to the following: H. A. Brouwer, Toel. Geol. Overz. k. N. O. I. bl. XVII, Jb. Mijnw., 44 (1915), Verh. II; J. J. Pannekoek van Rheden, Jb. Mijnw, 42 (1913), Verh., p. 15; the same, Geol. Notizen ü. Sanggar, etc., Z. f. Vulk., IV (1918), p. 85; the same, Nachtrag. in Z. f. Vulk., IV (1918), p. 306; F. M. Hühnerwadel, Eruptivgest. Nord-Mittel-Soembawa, Inaug. Diss. Basel, 1921; Joh. Elbert, in: Die Sunda-Expedition-Frankf. a/M., II (1912), S. 132-174; G. Rack, Petr. Unt. Ergussgest. Soembawa u. Flores, N. Jb. f. Min. etc., Beil. Bd., 34 (1912), S. 42-84.

the first known case of ash containing this mineral falling in historic times in the Netherlands Indies.

In addition to the diverse andesites--(augite-, biotite-augite, augite-hornblende-, and hornblende-andesite)--andesite-peckstone as well as black pumice stone also occur. In so far as is now known, dacite occurs only in the center of the island, especially on P. Liang, and then again behind Sapeh in the extreme east. The whole is, however, probably much more complicated than appeared upon first glance. In short, the geology is still incompletely worked out.

The SiO_2 content of these Soembawa rocks thus varies between about 65% and less than 49%. They are properly K and P-formation, they probably play a subordinate role.

Climate

With regard to the climate, similar conditions are found as on Bali and Lombok, though we have inadequate information.

Braak[40] records only a few particulars about the wind, borrowed from the report of Zollinger.[41] Rainfall figures over an adequately long period are available from only three stations: Taliwang in the west, in some degree to be compared with Mataram on Lombok and Tabanan on Bali; from Bima in the east, and from Soembawabesar (see Table 62).

Table 62

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SOEMBAWA[1]

Place (Location)	Elevation above sea level in meters	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Taliwang (West)	15	13	96	204	128	180	110	54	36	14	25	21	116	190	227	1305	7	5
Soembawa-besar (North)	20	21	78	243	245	249	92	46	16	14	9	12	54	111	210	1300	5	6
Bima (North) East	2	50	91	211	208	191	132	60	34	14	11	12	45	125	219	1262	6	6

1. J. Boerema, Regenval in N. I., Verh. Kon. Magn. Meteor. Obs., Batavia, No. 24, p. 210, up to and including 1928; corrected with the subsequently published figures of 1929 and 1930.

containing.--The so-called "laterite crust" is no pure product of leaching, for Si, Mg, Ca, Na, and K are still a long ways from being all gone, and yet the content of TiO_2 has already increased more than 5 times, that of Al_2O_3 only 1.5 times, and that of Fe_2O_3 about 2 times. Here landslides have occurred. The augite from the tephrite is poor in Si and Ti while strikingly rich in Fe, Al and Na.

What has been noted relating to clastic rocks on Soembawa is still too vague and meagre to go into here. Only the coral limestone reefs along the northern coast of the different parts of the island may be mentioned, although in soil

For the entire island these three rainfall stations are of course not sufficient. For instance for the higher center of West Soembawa, against the southern slopes of the volcanoes Sangenges, Sedeket, and Batoelanteh Zollinger states:[42] "The Batoe Lanteh is especially well watered.... The higher part of the mountain and the southwestern lower slopes are covered with beautiful forests." Without doubt on these slopes the rainfall is greater, the dry time less strongly pronounced.--Through "overmature tropical high forest" Zollinger pushed on toward the top of Batoe Lanteh. Here attention should be called to the fact that from there he observed that in the

40. C. Braak, Het climaat v. N. I., II, 3 (1929), p. 477, Verh. Kon. Magn. Meteor. Obs. No. 8.
41. H. Zollinger, l. c., pp. 84-93.
42. L. c., p. 56.

center of West Soembawa "the mountain Atas Kalaus" (Kelawis) "is all covered with cogon"[43] "while the lower slopes of Batoe Besawak" (on the newer map named Olet Bersanak) "in many places are bare."--If in 1848 that remote mountain land although extremely sparsely inhabited was already like that, it must either be very infertile, or else much less rain falls there. One is inclined to believe, according to the travel report of Zollinger,[44] that the land eastwards of this, to straight south and southeast of Mt. Batoe Lanteh, is a limestone mountain range full of sinks and hills, like Mt. Sewoe on Java. As a matter of fact, he calls the Setemper mountains "a kind of high land which consists of hundreds of rounded and nipple-shaped hills. They are mostly covered with cogon, and there is little water in the depressions lying between"..."formerly on the hills there must have been much teak forest. Now it has almost all been cut off...." Hence there must be a region with an already marked dry season, besides perhaps a west monsoon with a considerable rainfall.

Still farther to the east, however, the country becomes suspiciously dry, particularly in "the land of Lapie (Lape), where fresh water never was to be found" .... finally on the north side of the isthmus which connects west Soembawa with the eastern part, around Bima the climate changes to a true desert climate. However, on the southern side of the same isthmus, only 10 to 20 km. broad, in consequence of the rising air currents which come from the sea, much more rain falls. A single glance at the map shows at once this difference of climate. On the southern side are a number of small streams, on the northern side are many ravines, which during the west monsoon are intermittent streams that in the southeast monsoon remain completely dry. Zollinger's descriptions coincide completely with this picture.[45]

In short--we can no more correctly speak of "the" climate of Soembawa than of "the" climate of Java. In general it can said that in places with the most rainfall there is perhaps more than 3 m., but presumably yet never more than 4 m. while not more than a few localities will have more than 2 m. But the number of localities with less than 1 m. will undoubtedly be still greater, especially along all slopes toward the north and northeast, and in low regions with mountainous land to the southeast.

Ways in Which Weathering Occurs and Resulting Soil Types

Given the inadequate geological-petrographic basis, and the equally still inadequate figures of climatological observations, our discussion here is bound to be quite vague and full of gaps. Also in the lack of even a single agricultural officer, the absence of any description of the agriculture by an administrative officer is sorely felt. And a few sporadic observations which I made concerning the soil during a couple of short trips out from Soembawa-besar and from Bima, cannot make up for that.

In general, the following may be said, with this proviso, however, that from the start practically every statement should have confirmation: Before the great eruption of Mt. Tambora in 1815 apparently all the southwestern, southern, and southeastern slopes of the volcanoes were covered with brownish red lixivium from basic volcanic material, relatively mature or senile, varying in stage according to the length of time that these volcanoes had been quiet. Thereafter the soil on these slopes was more or less rejuvenated by the fresh Tambora ash. The slopes of the volcano, lying more to the north, especially those on the northeast, receive less rain, have a longer dry season and have therefore made less headway in the intermittent weathering (see Fig. 69, page 224). For this reason, and as a result of the less heavy erosion of the youngest ash, these northeastern slopes must be more juvenile, but at the same time drier.

As on Soembawa, contrary to the conditions of Lombok and Central Java,

43. (Imperata) spp.)

44. L. c., pp. 29-30 and 57-58.

45. L. c., pp. 22-23.

Photo by Le Roux

Fig. 69. Road along the East Coast of East Flores. In the background the Ili Mandiri volcano. Dry monsoon. Similar stony landscape with a few green and many bare trees is also found along the ascent west from Mborong on the southern coast of West Flores, as well as along the northwestern coast of Soembawa, east from Oetan. (See page 236.)

there are no great desposits of pale, fine pumice stone material. There is also not much chance that there will be found upon this island the corresponding heavy, black soils (rantja minjak) resulting from alternating weathering. It is true that Elbert[46] records a black soil: "In the higher parts (of the plain of Oetan) the Oetan river cuts the alluvial formations making steep banks. These are composed of a 1/2 to 1 m. thick cover of black, mollusk-rich clay and in places with a block-beach conglomerate, whose large and small rounded stones are cemented together by loam and coral sand."

But obviously this black soil has been formed subaqueously, as a shore swamp, and thereafter upraised. The Ca present in it appears to consist of shell fragments; lime concretions are not recorded, although the climate should make their formation possible. In the neighborhood of Oetan the author found on patches of bare black soil, about 1 to 2 m. above sea level, efflorescences of gypsum and of some other salt.

The lower one descends along the lower slopes of the volcanoes and finally into the few small plains, the drier the climate is, the smaller the part erosion plays. On the other hand, the greater the accession of fresh or scarcely weathered ash, the grayer is the color of the ground. The moving of this fine sandy ash has by no means been accomplished exclusively by flowing water. On the contrary, although quantitative studies have not been carried out, it appears that the wind plays at least as large a part in this.

Regarding the region between Ampang and Lopoh Zollinger's report of his tour

46. L. c., p. 40 of the reprint.

states:[47]

"In the neighborhood of Ampang one comes upon the dusty withered plain, which can best be described by the name 'desert.' The ground was so dry that it was split by thousands of cracks the width of the hand" (apparently it was a soil type with much clay, which was the cause of the strong shrinking). "The path between the two villages" (Ampang and Plampang, on the northern side of the southern isthmus) "runs through the most monotonous land which one can picture. Almost always the route along the coast is in a small plain which is covered so deep with ash that the horses sink in to their knees. The east wind drives the ash in great clouds before it so that one can hardly see the rider in front of him, and man and beast suffer terribly from the heat, from the dust and, of course, also from thirst. The Brang Rea, the big river, was entirely dry (19 Aug. 1847). The water loses itself in the sand. The coolies halted, dug deep holes in the sand in the bottom of which after a few moments they found water." Indeed, when here, one would not imagine himself to be anywhere in the "girdle of emeralds"--the Netherlands Indies.

Nor do conditions improve farther on. Regarding the route between Plambang and Lopoh, Zollinger writes: "Along the foot of the Djaran Poessan there stretches a hilly region bare and barren,....nothing growing at all. The grass upon the slopes is so withered that the yellow blades can be easily rubbed to dust between the fingers." The relative humidity of the air then must have fallen very low indeed. But on the opposite side of the mountain ridge into Soembawa-besar one gets back again into a rather moist small plain. So do the conditions of soil and climate on Soembawa change almost suddenly within a short distance.

Where marl and limestone occurrences are mentioned, these rocks appear as a rule to be tuffaceous. Now whether the soil on these formations will be exclusively red lixivium (terra rossa), as on Mt. Sewoe on Java, or black marl ground, is still to be learned.

Evaluation and Utilization of the Soils

If we, as in the Encyclopaedia of the Netherlands Indies,[48] draw extensive parallels between Soembawa and Java, as concerning geological structure and climate, then this question intrudes itself: why is there such a great difference in development between the two islands as to agriculture, culture, density of population, etc.?

In the first place Java has more plains; on Soembawa the low plains are small, and the mountains have few flat ridges or plateaus. Also, the rivers are short and their flow is variable and uncertain. Therefore irrigation cannot assume such proportions as it has on Java.

Even though it may be that the parent material of the soil may be just as good as in Java, the lack of regular supplies of water entirely alters the conditions. Water is "the" factor, upon which the agriculture stands or falls.

The higher mountains have localities where indeed enough rain falls, but in most cases the land there cannot be used, since it is quite too rough (see Fig. 70, page 226). Where the topography is flat enough, paddies or cultivated unirrigated upland fields are found; this is always so if the rainy season provides sufficient water. The people are quite willing and the soil is good. The development of agriculture of Soembawa is thus entirely a question of an adequate supply of water; and this comes down to a question of a rigorous reforestation of those mountain slopes which are too steep to cultivate. And, further, the construction of many small irrigation works is necessary for the checking of freshets in the wet season and for conservation of water for the dry season.

In spite of all this, whole subdistricts drop out where there is nothing to begin with. (For example, large parts of the north coast and east coast (see Fig. 71, page 226), and the entire eastern wing of west Soembawa, particularly Brangmojo, Ilir, Lape, Lopok and the lowland of Plampang). It will be fortunate if stock

47. L. c., p. 23.
48. Vol. IV, p. 8.

Photo by Mohr

Fig. 70. Eastern Soembawa.—View from the road between Bima and Sape, at km. 7 looking over the carefully cultivated plain in the midst of rugged, very much dissected mountainous land.

Photo by Mohr

Fig. 71. View toward the west southwest of Soembawa's northern coast, just west of the bay of Bima. Park landscape; green, shrubby trees, brown dried grass, grayish black soil, almost uninhabited. In the right distance Mt. Tambora, in the left distance the Soromandi mountains.

raising can be established and developed there. Whenever grass grows it is certainly nutritious, for the soil, mostly juvenile sandy Tambora ash, is fertile enough. And, with reforestation, a related question for stock raising is the creating or regeneration of springs where the cattle in the long dry season can find drinking water.

Given adequate water, rice and maize do well. Green beans and soy beans are limited to the lower, heavier loam and clay soils formerly raised up out of the sea. The fact that tobacco (for native use upon the island) is planted especially along the river banks, shows that the natives have learned through experience that this plant grows better on sandy alluvial loam land and with an adequate supply of water, than upon other soil types.

Anyone who visits in rapid succession West Soembawa and Bima is struck by the especially careful manner in which the Bimanese tends his agricultural fields. Regarding this Du Croo[49] says: "Through the greater density of population the people here feel much more severely the struggle for existence. They have to work in order to eat. In that respect the villager of the western part of the island is in much easier circumstances. Because of this the Bimanese has come to be a good and industrious farmer who devotes much care to his rice paddies and his secondary crops, which is especially evident in the cultivation of onions, for this crop requires much work (see Fig. 70, page 226).

Onions are for that matter a profitable export crop. Since onions are very exacting this also indicates that the soil is good and rich. (Cf. the Cheribon region of Java.)

Also lumbang is exported. The lumbang tree (Aleurites moluccana (L) Willd) does not do well on poor land. It only need be recalled how on Java in the Kendal plain this tree is found mostly along the southern edge of the plain, where it profits from what is washed off from the terrace lying behind along the steep wall on the higher ground.

For that matter it appears quite sensible to expand Arabica coffee cultivation on Soembawa on selected land above 1,000 m. elevation. There soil, climate, and population appear a priori in all respects to be suitable for that.

Meanwhile, whatever crop one may wish to encourage, it must never be forgotten that almost everywhere on Soembawa a quite marked dry season of a few months occurs. Where this is the case, trees such as teak and kapok which then lose their leaves are indicated. And the palmyra palm (Borassus flabellifer) which resists drought well is also at home in the dry regions.

In the country back of Bima I saw here and there the hardy bushy cotton (Gossypium herbaceum), as also cotton spinning in the village. Because of the importation of cheap (Japanese) cotton prints and thread the cultivation has declined. Perhaps it will revive again if an indigenous cotton industry will arise on Java. The staple is short, although beautifully white.

Summarizing we may say, however, that whatever crops may be cultivated, extended or introduced--the future of Soembawa stands a chance of being very promising, if the volcanoes remain dormant. Slowly, unobtrusively, without attracting attention to itself by world-shaking achievements, this island will develop into a land in many ways fruitful and prosperous.

* * * * *

As an appendix to the preceding about Soembawa, let us add a few words about the island P. Mojo to the north of it. Everywhere on the surface up to the highest point (about 600 m.)[50] is found lime (coral reefs). On the basis of the study of rocks collected by Pannekoek van Rheden[51] the strip of eruptives which he sketched along the northern edge has been divided by Hünerwadel[52] into andesites and basalt.

49. M. H. Du Croo, Cijfers en beschouw. betr. het eil. Soembawa., Kol. Stud. III (1919), p. 591-612.
50. Elbert, l. c., p. 43.
51. And presented to the Naturhist. Museum at Basel.
52. F. M. Hünerwadel, l. c.

Apart from that, the slightly hilly island in the form of a plateau, presumably for the greater part formerly covered with a layer of reef lime, was of course in 1815 strewn with Tambora ash.

Now it is worthy of note that, independent of the underlying rock (whether andesite, basalt, limestone or ash) the dry climate prevailing everywhere on this nearly deforested island permits only a savanna flora to come up. Lulofs[53] described it thus: "The vegetation has not the thickness and impenetrability of a true tropical forest. The trees and shrubs occur more scattered about, with open, grass-covered patches between them, so that the country, even without trails, may easily be traversed on foot, and even over great distances on horseback." This is the park landscape which may be seen from the sea, or expressed in a still better way: the tree steppe on this island reminds one of the films of the African steppes. And, like the latter, is inhabited by antelopes and other ruminants, as well as pachyderas. So upon P. Mojo are found countless antelope, wild swine and wild Balinese cattle, which have taken on the airs of bantengs. Whether the soil is now developing in the direction of black earth or terra rossa is still an open question. It appears most probable that for the time being it is still a brownish dark gray. But because of the pervious, iron-rich parent material, in the course of a long time it will gradually go over into terra rossa.

FLORES

Soil-Forming Rocks

If, with respect to the soil-forming rocks, we compare Flores with Java, there are found many points of striking similarity, but also points in which they distinctly differ.

Flores, like Java, is for the greater part built up of volcanic products. The geological sketch map of Ehrat[54] shows that, in so far as it concerns the mountainous land, there is as much or even more of the rose color indicating young volcanic rocks, i.e. andesites and basalt, as the map of Verbeek and Fennema shows for Java. Nevertheless Ehrat with a separate color from that for the more basic indicates the more acid effusives dacite and liparite. From the standpoint of the pedologist such a separation can only be enthusiastically applauded. On the map of Verbeek and Fennema which is 30 years older "V" (= "volcanic") still includes basalts as well as the most acid effusives of Java, such as for example, the Bantam white tuffs. In the most recently published geological maps of Java the same system of mapping has been followed, like also several sheets of the geological-petrographic map of Sumatra published in 1934. For those interested in the soil, these maps have all of the advantages of the map of Ehrat, and even more. For example, Ehrat differentiated basic and acid "effusives," but did not split the latter mentioned effusive into "Lava which flowed out" and "Blown out loose products or efflatas," which later can again become loose or solid tuffs. But these improvements are, however, on the Sumatra maps and fortunately also on the new Java sheets. If, however, a similar map of Flores should in due time appear, the areas which at present are indicated with one color (rose) will probably be separated into three subgroups, namely solid and loose basic products, besides loose acid volcanic products. At present, however, such a separation on the map is not possible, as the data are still too scarce and inadequately delimited. It can only be said that on Flores not only **V.a.1.**, and **V.b.1.**, but also **V.a.2** and **V.b.2** are to be found and appear as soil forming material. But regarding the relative areas there is still very little which can at present be recorded. Yet it may be deemed probable that in Flores more acid effusives[55] lie on the surface than in Java.

In the northern half of west Flores

53. C. Lulofs, Een land voor jagers., T. v. B. B., 50 (1916), p. 149.

54. Belonging with: H. Ehrat, Geol. Mijnb. k. onderz. op.Flores, Jb. Mijnw. N. I., 54 (1925), pp. 221-31? (versch. in 1928), there also a bibliography of additional literature.

55. See, for example, page 20 of this book.

Photo by Mohr

Fig. 72. Flores. Road along the Southern coast from Endeh toward Nangaroro, near Km. 16.--Pale, young tuff deposits; unconformity between lower and upper strata. Layers of differing erodability. Surface weathered to a dusty grayish brownish black soil: V.a.I.-- He.Nr.ae (I-2).

(Manggarai) there are great expanses[56] of marine sedimentary rocks; not only coral limestone and other limestones, but also marls with more or less clay and sand, besides globigerinas and other foraminifera. Besides these sediments there occur submarine deposited dacitic tuffs, as also numbers of intermediate forms, which according to the analysis can without difficulty be classified in Fig. 4. Also westerly from Endeh are found similar marine tuffaceous deposits. If one compares the shape of Flores with that of a fish, in the tail of it are tuffaceous deposits. The richer these deposits are in tuff material, the less the soil from them differs from the soil of terrigenous tuffs (see Fig. 72 above).

Although not covering large areas, but still more than on Java, granite and granodiorite occur in Flores, which in some places because of low amounts of quartz approach a diorite. Especially in the eastern part of Endeh district there is a quite large complex of these rocks, with characteristic soils.

Certainly the greatest difference however, between Java and Flores is that the extensive lowlands, which form well nigh a third of Java, are almost lacking in Flores or are at most a few percent of the whole. Flores is practically all mountains.

Pannekoek van Rheden[57] on his geological sketch map has surrounded Flores by the 100 fathom depth line, and one is then struck by its nearness to the coast, not only on the southern side, but also on the northern side. If the level of the sea should sink 100 m. the outline of Flores would change only little from its present form. In the west and the east a couple of islands would be united with it, but not more than that. Java on the contrary would become part of one large land mass

56. The so-called Reo-formation. See: J. J. Pannekoek van Rheden, Overz. geograph. geolog. gegevens enz... .... Flores, Jb. Mijnw. N. I., 40 (1911), p. 208-226. With maps (1913). --Since from Manggarai no satisfactory photographs were available, a few were included (Figs. 80-83) of P. Rintjah, an island which in all respects resembles West Flores and as such will serve the purpose.

57. L. c., pp. 212 and 213; see especially the map.

Table 63

Name.........	Pyroxene-andesite	Labrador-andesite	Labrador-andesite
Origin.......	Ndoea Ria East Endeh	Kpg. Nggadja Southeast Endeh	Bara volcano Southeast Endeh
Own number...	XVII	XIX	XX
Analyzed by..	Lindner	Lindner	Lindner
SiO_2	63.80	55.52	54.49
TiO_2	2.23	0.63	1.25
Al_2O_3	13.32	17.42	16.89
Fe_2O_3	3.29	5.14	4.88
FeO	2.30	5.35	5.44
MnO	0.24	0.05	0.04
MgO	2.23	3.30	3.35
CaO	4.63*	8.12	8.49
Na_2O	3.13	2.47	2.39
K_2O	1.53	0.77	0.94
H_2O + ...	1.34	0.36	0.87
H_2O	0.19	0.34	0.12
P_2O_5	0.18	0.15	0.28
SO_3	0.40	0.18	0
	99.60	99.80	99.67

* + BaO:0.70

comprising the bottom of the Java sea, Borneo, Billiton, Bangka, Sumatra and Malacca. Java's north coast would disappear. On the other hand, if the sea should rise 100 m. only small parts of Flores would be submerged, while of Java certainly more than 1/3 would disappear under the sea, including all the fertile and densely populated low plains. East Java would be replaced by a number of separate islands, the volcanoes.

Thus the kinds of soils originating from alluvia or colluvia, play only a very subordinate role in Flores. The soil characteristics are related to the volcanic rocks. Of these may be given a few analyses[58] which were not included in Part I. (See Table 63 above.)

* * * * *

Sample XVII is a fairly acid rock, but possesses just as little quartz as do the two others; the high TiO_2 content strikes one, just as does the low P_2O_5 content. This sample possesses no hypersthene, though the two last do. Samples XIX and XX are rich in Fe and Ca just as XVII is poor in P_2O_5. The petrographic analyses do not record any apatite.

Ehrat[59] likewise reports little apatite for basalts and andesites; only the Papang granites of the northerly Ngada possess "frequently much apatite." Hence it is not improbable that, if many data were available, Flores, in general, will prove to be poor in phosphorus.

58. See: G. Rack, Petrogr. Unters. an Gest. v. Sumbawa u. Flores, N. Jb. f. Min. etc. Beil. Bd., 34, p. 77
59. L. c., pp. 278-284.

Photo by Le Roux

Fig. 73. Flores. Highland of Ngada with the volcano Ine Rie at the left and the Langa mountain range to the right. Deforested by inhabitants; could be reforested, but each dry season the land is again burned bare, which hinders the soil from becoming as good as it could be.

Climate

Since the highest mountains (volcanoes) of Flores are only a little higher than 2,000 m. and none of them reach 2,400 m., there is no cold climate (**Ko**) in Flores. But the tropical climate of moderate temperature (**Ma**), to be found above 1,000 m., occurs a great deal for there are quite large plateaus between about 800 to 1,200 m. elevation, where at night it can become very cold and heavy fogs[60] frequently occur. In the dry season the differences between day and night temperatures are very great. For the plateau of Badjawa (see Figs. 73 - 75) an average air temperature of about 19° C is recorded. If it be taken into consideration that apart from grasses there is little vegetation here, and that moreover a large part is arable land with a dark sufacq soil, then--since regular observational figures of soil temperatures are still lacking--we may estimate the average soil temperature in the soil at from 22 to 28°C.[61] But in the thick clumps of bamboo, which are found in and around the villages, the average temperature will not go above 20° C and thus the climate will fall under **Ma**. Meanwhile the greater part of Flores, including the plateaus and slopes of the mountains, bare or sparsely coverèd with vegetation, remains warm and hot (**He**).

Regarding the water movement in the soil it must be pointed out that the plateaus mentioned are in no sense as flat as, for example, the plain of Bandoeng in Java. Here in Flores there is not much chance for water to stand on the surface of the soil, either continuously, or off and on for several months of the year. Everywhere the surface has quite sufficient

60. C. Braak, Het Klimaat v. Ned. Indië, II, pp. 477-478.
61. Compare Pt. I, pp. 42-45.

Photo by Le Roux

Fig. 74. Ngada region, Flores. Looking southwest from Badjawa to Ngada and the Wolo Atagai (right distance). Villages in bamboo groves. Well cared for cultivated fields, terraced. Surface soil dark brownish black. (See page 245).

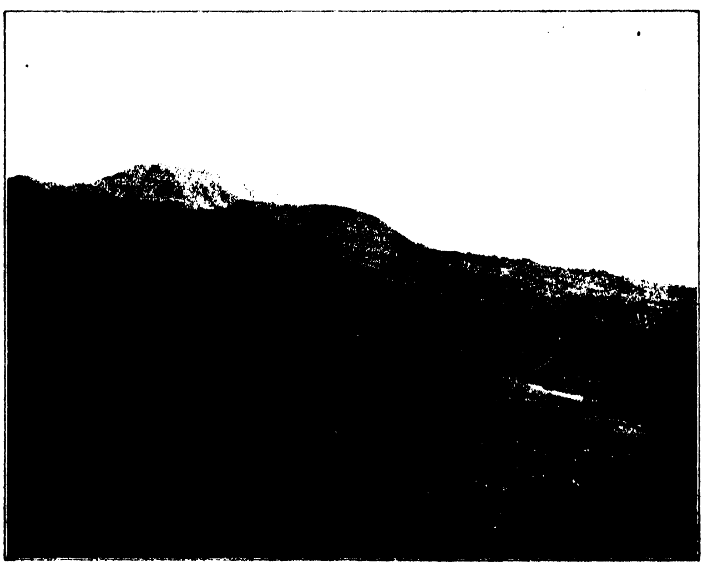

Photo by Le Roux

Fig. 75. Northeast slope of the Ine Like, Ngada region, Flores. Completely deforested by kaingin cultivation, fires, and severe dry seasons. Soil: dark brownish black layer OE on pale yellow E of V.I.--Wa.Nr.ae. (2-3). Garden cultivation of potatoes among other crops. (See pages 236, 243, and 245.)

slope, so that adequate drainage is possible and thus, with few exceptions of some **am** or **aq**, most of the soils of Flores weather under **ae** conditions, thus with much air.

Going into the rainfall, first of all the following figures (Table 64) are found:

the southeast and east. In the southeast monsoon the slopes ascending toward the west to north are the only ones which receive rain, the more as they lie higher. From the map it may be seen that the villages all lie on the east side, and even high up close to the summits, or even a little way over the top of the ridges or

Table 64

DISTRIBUTION OF RAINFALL DURING THE YEAR, ON FLORES[1]

Place	(Location)	Elevation above the sea, in meters	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Laboean Badjo	Northwest coast	2	13	72	168	163	111	70	42	19	15	3	11	27	62	188	878	4	6
Reo	North coast	50	20	58	278	349	201	60	35	21	18	24	10	16	50	192	1292	4	6
Roeteng	Western highland	1200	15	178	408	439	528	394	182	104	96	74	108	263	368	416	3445	10	0
Badjawa	Central highland	1250	20	110	415	378	310	185	96	36	57	31	16	45	167	374	2109	6	5
Endeh	Central southern coast	5	20	88	150	158	167	77	59	41	45	19	39	67	132	176	1130	5	5
Lela	Southeast coast	2	8	79	143	168	187	105	55	18	26	29	7	52	80	214	1086	5	6
Maoemere	Northern coast	2	26	65	157	168	159	[illegible]	45	27	12	9	6	25	78	175	960	4	6
Nangahale	Northern coast	2	9	79	456	475	290	218	74	11	3	5	2	22	75	349	1980	5	5
Larantoeka	Eastern coast	2	26	79	246	246	188	109	47	22	12	7	6	37	105	180	1207	6	6

1. Rainfall figures, taken from Verh. 24 of the Kon. Magn. Meteor. Obs. Batavia, p. 210, up to and including 1928 and corrected with the data for 1928 and 1930. Later data were not yet available.

These figures are still somewhat irregular averages since for several stations they run for but 8 or 9 years. But if one first keeps in mind the coastal places, the general impression is quite definite, namely, there prevails a distinct dry season, and an equally distinct wet season. In general, except at Roeteng, there are at least 5 dry months, usually more. Everywhere there are at least 4 wet months. At Roeteng, however, there are fully 10.

In this list Roeteng occupies an exceptional place. And it appears the reason for this unusually heavy rainfall is that true ascending-air-current rains occur. The wind comes from but two directions, from the southeast in the dry monsoon and from the west northwest in the wet one. In the rainy season the wind near Laboean Badjo loses but little moisture, since those mountains are still low. Once the wind is but across them and reaches higher land, then it must bring much rain to that latter place. In Nangahale in the east on the northern coast it must also rain harder than at Reo or Maoemere, since higher mountains lie behind in mountains which from the northeast run southwest toward the south coast. But of the valleys extending from the north toward the south or from the northeast toward the southwest the west-facing slopes and sides running up toward the east are extremely scantily covered with vegetation and very sparsely inhabited (see Figs. 76, 77, page 234, and Fig. 78, page 235). In a word: no rain, no vegetation, no people.

If in due time Flores is more thickly populated and developed, perhaps there can be a density of rainfall observations as there is now on Java. Then a map of Flores like Fig. 6 will apparently indicate some very remarkable features. One may expect that points will be found where still more rain falls than at Roeteng. And others will be found where it rains much less than at Maoemere. Presbumably for example, P. Padas Island (see Fig. 79, page 235) is a possibility for such a minimum figure, as well as the back country of Aimere on the southern coast (see Figs. 76 and 77, page 234), for this valley lies as much toward the west northwest as toward the southeast in the lee. In connection with the irrigation of the valleys see

Photo by O. Horst

Fig. 76. South Flores.--The Bay of Aimere, with in the distance the volcano Ine Rie. In front of it (left) the Langa Mts. This side of them the dry ridges, covered only with grasses (see Fig. 77) dropping down toward Aimere, on the coast. On the right a big sand bank with nothing else than palmyra palms (Borassus flabellifer). Foreground: slope ascending toward the south, moister, with more forest.

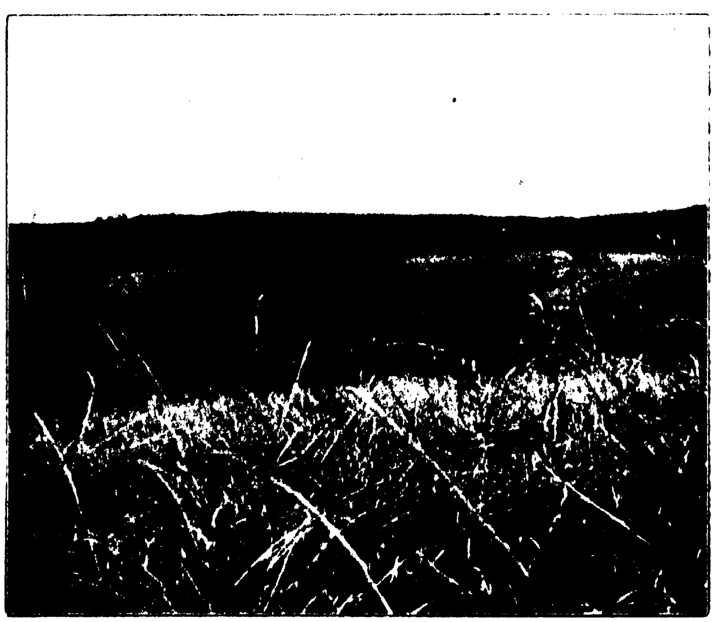

Photo by Mohr

Fig. 77. Along the road from Badjawa dropping down toward Aimere, Southern Flores. Uninhabited, lower slopes, Andropogon contorsum in

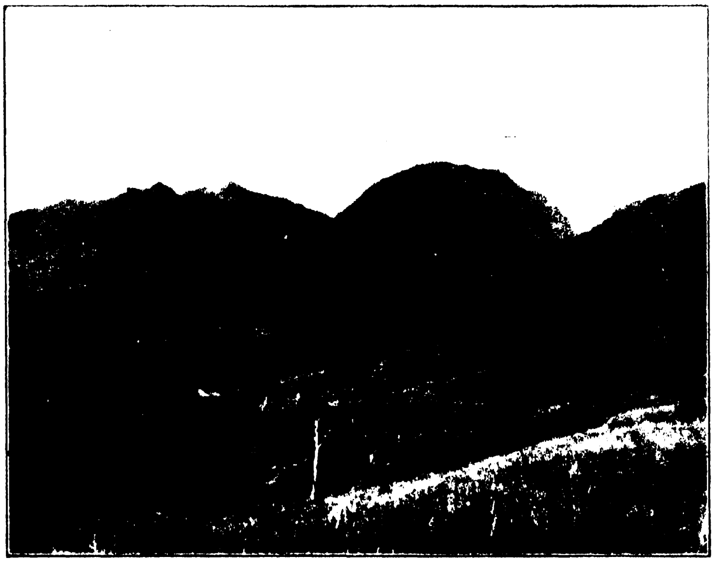

Photo by Le Roux

Fig. 78. Central Flores. The (extinct) volcano Geli Ndora in the Naga region carries forest on the top. Lower down the forest struggles against kaiñgining and burning by the natives.

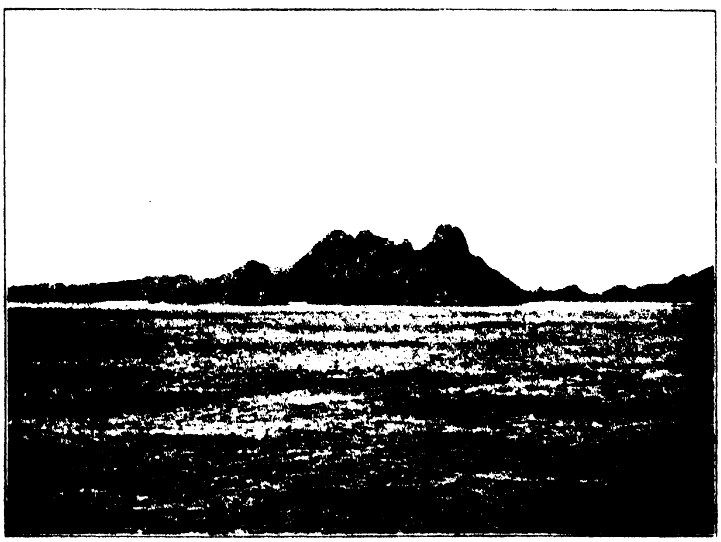

Fig. 79. The smaller Soenda Islands. Padar Island, Lintah Strait looking out toward the east northeast.—At less than 9° South Latitude the rocks are bare, because of the intense dry seasons.

page 244.

In localities as Roeteng it is obvious that **NN** or **nn** should be used to indicate a continuous leaching out of the soil. But for practically almost all of the rest of Flores, however, the symbol is **Nr** or **nvv**, (intermittent leaching out).

The vegetation exhibits all forms from moist rain forest, park landscape, and savanna with trees to treeless savanna. The trees which can withstand the rainless period the longest are palmyra palms (Borassus flabellifer) and a few dwarf trees and shrubs, which moreover because of the nature of their bark are capable of withstanding the fires in the dried grass which repeatedly occur. Yet the following rainy season they are able to burst into leaf (see Figs. 69, 75, 77, 78, and 80-84).

Ways in Which Weathering Occurs and Resulting Soil Types

From the foregoing it follows that the most important forms of weathering for Flores must be: **He.Nr.ae** and (**He** to **Ma**). **NN.ae**, the latter particularly on continuously rainy mountain slopes. Since **V.a** and **V.b** have been supplied alternately by the various points of eruption, with much efflata (**I**) and a few lava streams lying on the surface (2), the formula which predominates over all others is **V.I--He.Nr.ae (I-5)**.

In order to test this satisfactorily, we should have at our disposal at least one or more detailed soil descriptions from Flores. Thus far however these are lacking. It is true that in some publications[62] which treat of Flores alone or of Flores among others, a few sentences are to be found which give some suggestions as to the nature of the soil. In addition the notes I took during my travels in Flores in 1931 are at hand. As instructed by the Colonial Institute, I travelled from Endeh eastwards to Maoemere, and westwards a long ways north beyond Roeteng. The following is a summary of the data we now have about Flores soils.

From the standpoint of the soil the division of Flores from the west towards the east into the 5 political subdivisions: Manggarai, Ngada, Endeh, Maoemere and Larantoeka, is inadequate. More important for our purposes is the watershed between the north and the south, which with a few bends runs along the entire island from west to east, and splits the first mentioned 4 subdivisions into northern and southern parts. The volcanoes, approximately a dozen, which today still have the reputation of being active, all lie on or to the south of this watershed.

In south Manggarai, which geologically is young volcanic, the volcanic activity, seen from the standpoint of soil science, appears to have ceased a considerable time ago. This is because the climate, especially due to sufficient rains, has occasioned a good deal of weathering. For example, the small plain of Mborong, lying on the southern coast, since it retains considerable moisture, and at the same time receives additions underground from the back country, is covered with high swamp vegetation. Now if we ascend from this plain toward the north, we pass through and along all forms of soil and vegetation, which in the whole south of West Flores again and again repeat themselves (see Figs. 76, 77, 80, and 82). As soon as we have ascended but a few meters out of this plain, we find ourselves (in July!) on barren, dry land, where scarcely enough dried grass stands to be able to burn off. The soil is dusty, pale, juvenile. Originally it was calcareous, since here are elevated coral reefs, alternating with old, but almost unweathered layers of ash. A distinct profile cannot develop here, for in the dry monsoon the wind blows over the surface and carries everything away and in the rainy season the rain erodes off the bare surface, before any protecting vegetation develops on it. Thus nothing but some miserable grass grows. No people live here,--not even a single village is to be found. Along a ridge running north and south the road rises higher and higher, now for a time remaining east, then moving west of the summit. At a couple of hundred meters elevation appear isolated separate little dwarfed trees and shrubs, then follow groups of them (see Fig. 69). The difference between the eastern and western sides is remarkable. For a

62. See Ehrat, Pannekoek van Rhoden, Elbert and others.

Photo by Le Roux

Fig. 80. Rintja Island, near Flores. Vegetation of grasses and palmyra palms (Borassus flabellifor) (savanna climate!). In the distance are Padar and Komodo islands in Lintah Strait.

Photo by O. Horst

Fig. 81 Rintja Island near Flores.—Climate with severe annual drought. Slopes bare. Low plain with good forest.

Photo by O. Horst

Fig. 82. West Flores.--Rintja Island.--Heavy water and wind erosion, owing to which hardly any soil is left behind.--Uninhabited region (no water). (See pages 229, 233-36.)

Photo by O. Horst

Fig. 83. West Flores.—Rintja Island. In spite of the long continued, strong, dry monsoon, where there is water as along the coast or in depressions, forest grows. Elsewhere only savanna on the pervious calcareous tuffs. (See pages 229, 233.)

Photo by Le Roux

Fig. 84. Central Flores.--East Endeh region.--Mboeli mountains.-- From the very rough tuff slopes much fertile surface soil has been eroded off into the ravines; cocos are growing everywhere on the lower slopes.

Photo by Mohr

Fig. 85. Panorama somewhat south of Boawai taken from the highway looking north northwest over the valley of the Lowo Gio, Ngada region, Central Flores. Juvenile, pale brown soil on slightly acid young tuffs: V.a.I.--He.Nr.ae I/2. Cabo negro palms (Arenga saccharifera Labill) preponderate in all the little ravines.

considerable distance the slopes facing toward the east continue to be savanna, while those facing west exhibit spots of forest. Still higher between the patches of forest, cultivated spots begin to appear, while on the eastern side all areas are untouched and uninhabited. Then on the western side villages begin to appear; easterly there is still nothing. Near Sita village, at perhaps 400 to 500 m. elevation, from the road cut through the summit of the mountain ridge it appears that the soil has already gone beyond the weathering stage **Nr.ae (1-2)** to **Nr.ae (3-4)**. The humous surface soil **oE** is very little developed, most times practically wanting. **E** is light brownish red, a tolerably heavy lixivium, in some places as much as several meters thick. Lying under that there is a layer, which is best designated by **V.2--He.Nr.ae.2**. Coarse rocks (moderately acid andesite) in an already reddish brown oxidized soil in a transitional stage from **D** toward **E**. That here no white clay layer has developed under the layer **E** will probably have to be ascribed to the steep slopes and rapid run off of the rainfall.

Going still higher, above 1,000 m., beautiful luxuriant forest is found. A good example is around the little lake Rana Mese. This is a "blow hole," like several which lie on the mantle of Mt. Lamongan on Java. The lixivium **E** has now changed from a reddish brown to a more yellowish brown. **V.b.** appears to incline toward **V.a**: **Nr** going over into **NN** and **He** into **Ma**, so that the formula becomes: **V.a--Ma.NN.ae (2-3)**. Here in the forest on **E** lies a clear, sometimes 1 ft. thick layer **oE** of dark brown color, very rich in humus and crumbly.--Going out from the forest on down again toward the nearly bare plain of Roeteng, the following transitions are observed: **oE** becomes somewhat thinner, but more brownish black, **E** also becomes thinner and paler, brownish yellow to yellowish white. This lies on **D**, which sometimes has many stones, and sometimes contains considerable smaller and porous gravel, almost pumice stone. The lixivium **E** exhibits clearly the "mountain granulation" (see page 150).

To the south of the great divide the picture sketched here repeats itself on Flores several times so that even for places which were not personally visited, the soil can be described rather definitely. Local variations with respect to the parent rocks, climate, vegetation and stage of weathering, will, however, have to be considered.

Speaking generally, after surveying the whole, we come to this conclusion: where adequate rain falls, and especially where it rains continuously, the surface soil is weathered to stage **3-4**, while where the dry monsoon is long and hot usually stage **1-2** has been reached. Since the parent rock is not above the average in richness, and is usually somewhat toward the acid side, it is but seldom that we find the combination wherein a luxuriant vegetation accompanies a long continued fertility. Something is always lacking. Either the rocks possess too little P, or the soil throughout the year is considered too dry, or the soil is already too senile as a result of heavy rainfall. The last case can be very clearly observed in the strip to the north of Roeteng and nearly to Pagal.

Here we come to the older terrain, namely the already barely mentioned Tertiary Reo formation, which apparently in geologically Recent time has not been covered by fresh volcanic products. The soil is thus already old as soil. Under a practically treeless cogon[63] and talahib[64] grass plain lies red lixivium: **V--(He-Ma).NN.ae (1-5)**. The profile consists of a very thin layer **oE**. This is underlain by a heavy red horizon **E**, which sometimes decreases in thickness from 2 m. to almost nothing. Next below is the "mottled clay" I_2, reddish to bluish white with red flecks, with iron concretions (I_3) above it. Under it are many fragments of chalcedony I_1, this horizon being the residues of the silicic acid precipitation during the early stages of the weathering process. If this profile sketch be compared with the Frontispiece A, then it will be seen that the last part of stage **4** has been reached and even stage **5**. This also explains the poor vegetation, which probably obtains the inorganic food substances it needs from the dust carried in between the showers by the

63. *Imperata* spp.

64. *Saccharum spontaneum* L.

dry wind from the southeast.(see Fig. 66). If we consider the colored profile of Vageler[65] of a "laterite-red-earth," the profiles to the north of Roenteng are in agreement with that but yet some differences exist. According to Vageler the organic matter in the red earth E amounts to only 1/2 to 1 1/2%, which certainly is not much. But the iron concretions between the white clay and the red earth are lacking and occur only on the surface. However, according to Vageler's description, his profile is one which has developed under an entirely different climate.

In this connection it is worth while to consider what Ehrat[66] who, except for this, carefully shuns every observation relating to the soil, records relating to the occurrence of iron ore in Flores. At a number of places in North Ngada, in Manggarai, on P. Rintja and P. Komodo these iron ores occur. "The limestone mountain Wolo Besi, near Papang has iron ore on its two peaks."--"On Wolo Bopo....there is likewise a small occurrence of iron ore."--"On Wolo Akoer....there extends along the top and the western mountain slopes over an extent of about 300 x 80 m. a field of iron ore blocks."--"To the north of Soa in the drainage of the streams Wai Bero and Wai Mere there is a limonite occurrence..... It is nothing else but a weathering product, in layer form and in crusts originating out of the tuff layers....the possibility is excluded that this limonite might have originated as a ferruginous cap from sulfide ore veins."

Apart from this, however, these minerals which accompany iron ore--quartz, chalcedony, manganese superoxide, and in addition pyrite and copper ores induce Ehrat to accept, for the origin of all these minerals, a contact metamorphosis. For some of the occurrences I will gladly accept this method of formation, but there are other materials which, based upon what has been discussed in Part I, are more evidently to be considered as weathering products, namely as concretions (I_3) of the above profiles described for Manggarai (chalcedony, quartz).

Elsewhere on this Reo formation, presumably where these marine deposits developed less from fresh volcanic material than from clay and lime, the weathering is characterized not so much by **NN** or **nn**, but by **nvv**, and the soil is <u>black</u>. Already in 1891 the Controller Meerburg[67] recorded: "The small plain at the foot of the Golo Namoe" (indicated on the topographic map of 1928 as G. Tjode), one hour to the southwest of Tjiba, has four....creeks flowing through it, but they give no fertility to the <u>black</u> and red earth." Also on the plateau of Roeté (Roeteng) "it happens that a few shallow brooks bestow on the land no fertility, for the plain is covered only by cogon."[68] Forty years later the aspect was not much more favorable. Meerburg states (page 478): "There in the center of the land all tree growth is lacking. Predatory cultivation upon a big scale must have occurred there since immemorial times." This, perhaps, is just. It is still a question, however, whether this is the whole truth, for it is not at all improbable that since time immemorial the soil has been too poor to grow a thrifty forest.

Notable also is the remark of Meerburg (page 479): "Lowland rice culture is unknown in Manggarai; only around Reo is it carried on." That also indicates not only an extraordinary senility of the soil, but at the same time the poverty of the water of the region.

* * * * *

Located in the center of Ngada are the plains of Soa and Lambo, with a soil which differs from the general picture for Flores. If these plains are crossed from the south toward the north, then the brownish yellow soil, covered with a blackish brown surface soil, is seen to gradually change into the familiar <u>black</u> of **V.a.I.**--

65. P. Vageler, An introduction to tropical soils, translated by H. Greene (London, 1933), Plate VIII, facing p. 166.

66. Ehrat, <u>l. c.</u>, pp. 303-307.

67. J. W. Meerburg, Beschr. Midden-Manggarai (W. Flores), T. schr. Ind. Taal-, Land- en Volk. k., <u>34</u>, (1891), p. 434 ff., especially p. 438.

68. (<u>Imperata</u> spp.).

He.nvv.am (3-4). Pannekoek van Rheden[69] described the parent material thus: "A well layered complex of light yellow, very fine granular soft tuffs with many layers of lapilli and volcanic sand lying between. Here and there this stone resembles marl, still the lime content remains very small." Van Rheden considers it "not improbable that this complex was deposited in a fresh water basin."--Without wishing to discuss further this hypotheses I may add that the position of the originally flat soil has been considerably altered technically for now neither plain is by any means horizontal and near Djawawawo, near the Aimere river and the locality of the "Lambo" plantation the black soil exhibits similar undulations as does a similar soil in East Java. It is just the same heavy, cracking, black clay soil, only probably much poorer in plant food substances than its relatives on Java, Madoera, and South Lombok. A few small lime and iron concretions occur in it. The thickness of the black layer varies from 2 to 6 meters.

* * * * *

If one rides out from Endeh, and after crossing a few kilometers of sea and river alluvium planted to coconuts, continues toward Maoemere, one passes first an extraordinarily rough volcanic region of andesitic rocks with as a whole only little soil on the steep slopes (see Fig. 84). At about km. post 25 the "plain" of Noetoesoko is reached, which in comparison with the inhospitable, rocky terrain just passed might be called a plain, though in comparison with true flat land it is rather an undulating broad valley. Here the soil is deeper. Here and there a dark crumbly layer of E of a foot depth lies upon a warm brown subsoil. This soil formation continues to about Wologai. To the left on the other side of the Lowo Ria on a bare ridge parallel to it, running from the southwest toward the northeast, may be seen an entirely different soil. It is pale red in color and has arenga palms (Arenga pinnata (Wurmb) Merr.) scattered over it. South of this river these palms occur but very sporadically. Whether under this red soil, which is unusual for this part of Flores, is a granite or some other divergent rock, cannot now be made out. Geologically this region has not yet been investigated. On his map Ehrat leaves this locality white.

On the saddle of Wologai the road cuts into pale tuffs. The soil is thin, and judging by the vegetation, it is only slightly fertile. Perhaps it is also not able to retain sufficient water. In the small plain of Pamoeria, near Noetoesoko the soil is better. It is a brown lixivium with dark cultivated surface soil. Descending from Wologai toward the plain of Moeni through the Wolowaroe valley and then up again to Tabawee, the road runs through a large body of granodiorite. This rock carries a weathering cover of brownish yellow lixivium (E) with a layer of E for the most part quite thin, and of somewhat darker tint. Where E is shallow, from 1 to 2 m. deep, the soil is crumbly. Where E is some meters deep, the soil is more senile, more massive, and heavier. The fertility here is not bad, but the rough topography retards the development of a luxuriant vegetation, since the original vegetative cover has been all kaingined off in the course of shifting cultivation. Beyond this region we again find poor pale tuffs which extend to Liatola on the coast. As far as Paga the tuff region is miserably dry, though beyond there it improves a little. The Kimang-Boeleng mountains seem to be of better andesite, for the tuff sand banks south and southeast of it are covered with productive coconuts to the tops of quite steep ridges and small plateaus. In spite of the dry climate these banks and ridges must conserve adequate moisture from the rainy season of a half year before in order to provide the trees with adequate moisture. It is true that in the hilly land, around Nita for example, there is somewhat more rain. But over the ridge, going down toward Maoemere the rain becomes less and less.

Then the grayish brown tuff sandy soil of the coconut region gradually changes to a black soil upon an almost unweathered grayish subsoil of tuff sand and gravel. This dusty black soil, looks like

69. L. c., Jb. Mijnw. N. I., 40 (1911), p. 220-221.

the soil of the saddle between the Idjen and the Baloeran mountains in East Java, but is full of lime concretions. The parent material is quite basic andesite, having come in as a lahar from the west and southwest. Hence the formula is: **V.b. (I- + -2)--He.NS.ae (I to 2)**. Actually I saw this soil type only in the environs of the Nita-Maoemere road (see Fig. 26, page 156). But to the north of the divide it almost certainly stretches out far toward both the west and the east.

If more rain fell, the fertility of this region would be greater, but few trees and shrubs can stand a dry season of sometimes over 7 to 8 months. The soil reaction is without doubt on the alkaline side, at least in the dry season. More toward the sea, thus back of Maoemere, the soil becomes somewhat richer in clay, hence, **He.nvv.am.2**. Here tobacco is growing on this soil, and the plants look quite vigorous, even after a three months' dry season.

Evaluation and Utilization of the Soils

An observation already made (page 240) may be stated in different words: where enough rain falls, the soil is not rich, and where the soil is rich, enough rain does not fall in Flores. This is apparently not a very favorable prognosis for the development of the island as an agricultural region. The situation is not hopeless, for man can, by means of technical skill, turn unfavorable factors into favorable ones. But the present day inhabitants of Flores cannot yet do this.

Up to now the agriculture on this island is, for the greater part, primitive. The agricultural knowledge and technique of the Hindus which have proved so satisfactory on Bali and West Lombok, have not penetrated to Flores. Here the inhabitants still practice principally kaiñgin cultivation, a form of crop production which may be defended to a certain extent for regions with a very thinly-scattered population. This system is also better adapted to a climate with so much rain that after the abandonment of the kaiñgins, natural forest grows up again, until at a certain height it can protect itself. But on the greater part of Flores with its long dry periods, on an abandoned kaiñgin only a thin vegetation of grasses will grow which will frequently burn off or is intentionally burned off (see Fig. 75). Here the soil is further impoverished by this treatment and as it lies bare it is robbed of the most valuable part of its cultivable soil, by water erosion or wind erosion. If we accept the estimate that the forests of Flores now amount to only about 10% of the total area, then there are not more than 10 ha. forest for 35 people. A great deal of this occupies the high peaks or inaccessible slopes. It will not be too far from the truth to estimate an average of approximately one hectare of still accessible forest per family. That is not much for a kaiñgining people! In reality the new clearings are by no means mostly made on forest land; instead a large part are on cogon land. And from such land rich harvests are not to be expected. Correctly the Assistant Resident G. A. Bosselaar writes[70] "that with the methods of cultivation followed at present good arable soils are scarce. As a consequence, in the future the population of Flores is menaced by the probability of arriving at an impasse, which will bring with it very disagreeable consequences."

The only solution is increasing the intensiveness of the agriculture, by which means an average higher harvest per unit of area can be obtained. Then the kaiñgin "cultivation" will have to make way for fields continuously in cultivation, and this is possible only through assurance of a source of irrigation water, in the localities with rich, but as a rule too dry ground. In the tracts with adequate water but poor, senile soils, it is only possible through fertilization. But irrigation and fertilization, however, cost money. Hence Flores will have to begin with an export of excess agricultural products. It is up to the agriculturists and economists to solve this question.

Here the only question is: is irrigation possible?--From the technical point of view it most certainly is possible; but whether it is also practicable economically, is quite another question. At present in

70. Mem. v. Overgave, 10 Febr. 1932, p. 29.

many broad valleys of the island the condition is this: The excessive rain of 4 to 5 months runs off with great speed from the bare slopes toward the sea. In two different ways this water might be held back. Firstly through a slow but continual descent of the afforestation downward from the tops of the mountains to the bottom; the beneficial influence of such an increase in the forest certainly does not need to be stated here. Secondly, however, by making use of the loose stones occurring in so very many places in such great quantity on the higher lands, build up terrace walls of approximately 1 m. height running horizontally, and in this way induce a natural terracing of the land. Certainly behind these little walls, soil eroded from higher points will accumulate by itself, and become good arable land. At the same time the speed of the water is reduced, hence more of it penetrates into the soil. Thereafter favorable spots can be irrigated in a simple fashion and so perhaps make a beginning in lowland rice culture in localities where, up to the present time, it is lacking.

But to immediately consider larger irrigation works--apart from the difficulty of the high cost--may certainly be considered as premature. The inhabitants of Flores are neither Balinese nor Toradjas. In general, they still have a great many things to learn before they are as advanced as those people. The agricultural Extension Service finds in Flores a field of endeavor with a very attractive perspective. But excessive haste in placing good irrigable land at the disposal of the farmers would most probably lead to disappointment. Flores should not be compared directly with certain regions of Java or Sumatra, for some differences must of course be taken into consideration: 1st in the parts of Flores suited for raising rice or maize the parent rock of the soil is probably different (perhaps distinctly poorer in phosphorus) than in Java; 2nd, the topography, in general, is very much rougher and large plains are lacking, so that one really finds oneself among irrigated mountain rice terraces, with short rivers in their rear, and 3rd dry monsoons are more pronounced than at the same elevation in Java.

In the high region of abundant rain about Roeteng in Manggarai, there is another problem: much water, but poor land. We have already quoted (page 241) Meerburg's observation:[71] "The small plain at the foot of the Golo Namoe has four creeks flowing through it, but they impart no fertility to the black and red soil." Evidently fertilization is necessary. We think at once of stable manure. It is true that as compared with East Flores, Manggarai has a larger number of live stock, cattle, carabao, and horses, but even West Flores has not as many cattle as Madoera. Yet every little bit of manure helps, particularly if it is properly conserved. Commercial fertilizers are too expensive as long as no high value export crops are raised with success. Not unlikely in a more distant or perhaps already near future, it is possible to extend and increase the intensity of potato and (arabica) coffee cultivation, in the higher regions.

In addition to the small coastal plains which have an adequate quantity of water in the soil, as can be seen in wells or pits at shallow depth, a successful coconut culture is found in the very rough, hilly tuff country to the south of Maoemere. In the middle of the dry season it is a wonderful sight to see the trees in full flower and with a full crop of nuts standing on this sandy tuff, sometimes right up to the edge of steep slopes. Apparently in the rainy season this tuff is in a condition to take up adequate moisture and to store it up, so that the roots of the cocos are well supplied during the entire dry monsoon. Because of this, the environs of Nita can be called very fertile. If in the many larger and smaller valleys to the south of the main watershed which runs through Flores from the east to the west, river water could be brought onto the soil near the rivers, then without doubt great fertility should be produced where at present thick clouds of dust are blown up from hopelessly dry fields.

Flores shows promise for other crops than coconuts, for example, kapok. This crop does well on small plots of ground, door yards for example. Moreover

71. L. c., p. 438.

it should be planted in such a way that the trees are widely separated from each other and obtain adequate moisture in the dry season. It does best on brown lixivium or on grayish brown juvenile tuff soils.

That kapok however does not succeed everywhere on Flores, appears from this example: On the Lambo estate, in Ngada, some kapok was growing as an experimental planting, on black soil: V.a.I--He.nvv. (3-4), but it was not successful. The little trees apparently suffered a lack of everything. Even in the rainy season they didn't make any progress. Thus a lack of water was certainly not the principal factor. Presumably P, K and N were all lacking, as the dwarfish growth and yellow leaves might indicate. After having seen the test plantings of rubber (small, thin, poor), coffee (many yellow leaves and very little fruit) and sisal (short and lank), I could not suppress the impression that the land was extraordinarily poor, and without heavy complete fertilization nothing could be expected. Yet this is a type of soil similar to that in Java which produced enormous yields of sugar. But at the same time one must bear in mind the very heavy expenditures which have to be incurred for irrigation, cultivation of the land, fertilization, etc. to obtain these results on that soil. It will be a very long time before Flores will attain this stage of agricultural development.

That thus far the cultivation of cotton has turned out badly was not a question of the shortcomings of the soil, but more one of diseases and pests. If measures to combat or rather to prevent these troubles succeed, then the raising of this fiber is certainly not impossible, particularly in the low, warm regions, with a long dry season and at the same time adequate moisture in the subsoil still accessible for the roots.

Without losing sight of the production of export products, the Agricultural Extension Service is directing its attention to the intensification of the cultivation of food crops, including vegetables and fruits (especially also on the plateaus, see Figs. 74, 75) where with the soils and climate found there adequate success may be expected for the time being.

* * * * *

SOEMBA

Soil-Forming Rocks

Soemba has not been adequately studied geologically [72] and consequently one cannot make a composite geological map from the available data. Still we find in a few publications enough information to be able to give us some idea of the extent of the important parent materials for the formation of soils. On his reconnaissance journey over Soemba in 1891 Ten Kate collected a large number of rock samples. These were determined by Wichmann, so that in the report of his journey,[73] which appeared in 1894, Ten Kate could make use of the determinations. In 1899 Verbeek[74] could devote only 4 days to the investigation of Soemba, and most of this time was taken up in his circumnavigation of the island. And although he was capable and experienced, he could add but little to the knowledge of the geology of Soemba. Important, however, was the information obtained by H. Witkamp[75] during his meritorious reconnaissance. Since then no publication of importance relating to Soemba has appeared. Thus Witkamp is still (1934) the most important source of data from which we can construct a connected picture of the geological structure and the nature of the soil of Soemba. Brouwer[76] has already briefly done this. It is, however, the petrographic nature of the uppermost (soil forming) layers that is especially important for us.

72. It is possible that there has been more investigated than published; but what is unpublished was not available when preparing this description.
73. Herm. F. C. Ten Kate, Reisversl. Timorgroep en Polynesië, T. Kon. Aardr. Gen., 1894.
74. R. D. M. Verbeek, Molukkenverslag., Jb. Mijnw. N. I. (1908), Wet. Ged., p. 294-300.
75. H. Witkamp, Verkenn. tocht. o. Soemba, T. Kon. Aardr. Gen., 1912 and 1913.
76. A. H. Brouwer, Geol. Overz. Oost. ged. O. I. Arch., Jb. Mijnw. N. I. (1917), Verh. II, p. 341-342.

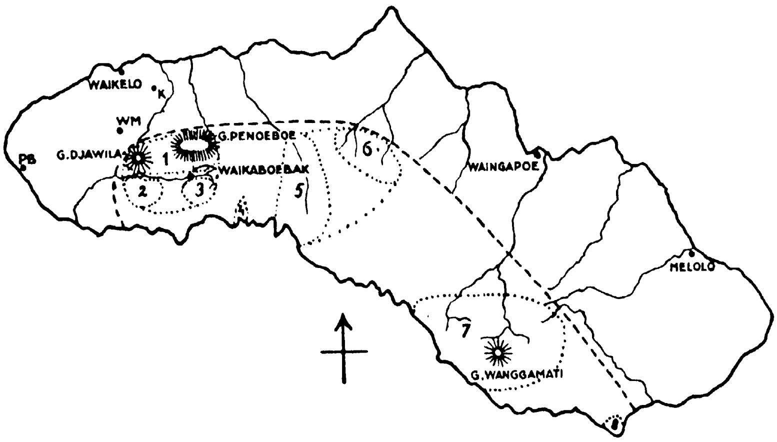

Fig. 86. Geological sketch map of Soemba Island.

While it could be said of Flores that the greater part of the surface consists of volcanic rocks with the kinds of soils formed from them, while only a relatively small part, especially the northern half of Manggarai, is occupied by (Tertiary) marls, marly limestones, and limestones--Soemba, on the contrary, appears to be covered over with predominantly weak and harder marls and limestones. Igneous rocks appear from under the sedimentary rocks as mountains and mountainous land only in the region lying to the south of the curved line which bisects the whole length of Soemba from the east to the west, and even then not everywhere. From this map (Fig. 86 above) it may be seen that in the central part the marls run through uninterruptedly to the southern coast. Also in the east (insofar as is known) the country is almost all marls nearly to the southern edge. Of the western end, nothing geological is known--at least nothing has been published. The igneous rocks which have been found are the following:

1. In the west: a complex of three bodies of mountainous land (1), (2), and (3) between which are marls; while one of the components of the mountains themselves here and there is likewise this same Neogene sedimentary rock.
2. More toward the center of Soemba, are two bodies (5) and (6) within which the marls are also present.
3. In the southeast the highest part of Soemba, namely the regions Taboendoe and Massoe (7);
4. A couple of small points (4) and (8) close to the southern coast.

More to the north in (1) are found andesite and basalt, while more to the east are diorite, gabbro, and diabase. In (2) besides basic eruptives there are also acidic ones (rhyolite), and in (3) again basic eruptives.

In (5) and (6) are found diabase, porphyrite and melaphyre, more easterly quartz porphyry and mica andesite tuff. In (7) andesite and diabase porphyrite predominate but other igneous rocks also occur, even granite and pegmatite.

Besides these magmatic rocks in (2), (3) and (7) there are found here and there old quartz sandstones, moreover pumice stone and pumice stone tuffs occur in many places. Sometimes the "marls" have only a small proportion of lime and clay; and especially around and close to the principal region of the eruptives the principal component is often pumice stone gravel.[77]

Though a new study by Roggeveen

77. P. M. Roggeveen, Abyssische u. hypabyssische Eruptivgest. d. Insel Soemba, Proc. Kon. Akad. v. Wet. Amst., 35 (1932), p. 878-890.

Photo be H. van der Mooren

Fig. 87. Near Waingapoe, Soemba. Trees standing bare in the dry season. Soil a (thin) grayish blackearth with lime fragments and some fallen leaves.

of the rocks collected by Ten Kate and Witkamp gives them more or less revised names, it alters but little the general character. Apparently no chemical analyses of Soemba rocks have yet been carried out.

In general we can safely say that almost everywhere on Soemba the Neogene possesses eruptive material to a greater or lesser degree. Sometimes it is in the form of already deeply weathered cobble stones, then again as fine gravel, so that in such places the soil must necessarily carry traces of them.

From the north-northeast toward the south-southwest the land ascends gradually. The mountains of eruptive rocks are the highest parts. They are thought to be surrounded, toward the north-northeast, toward the west and toward the east by a zone of marly marine tuffs, beyond which follows a zone of tuff marls and finally preponderatingly calcareous marls. This is obviously but a rough sketch: if we went into detail much more might be said.

Climate

Soemba has only very little coastal plain, and no high mountains at all. In the western half none of the mountain tops exceed 900 m.; the Djawila (887 m.) and the Penoeboe (830 m.) are the highest region of the island, with several summits above 1,000 m. but even here not a single one is above 1,250 m. The highest is apparently Wangga Mati in the Massoe mountains with an elevation of 1,225 m.

As to temperatures, hardly any part of Soemba can be said to have a cold or even a temperate climate. This island lies almost entirely within the zones **He** (0-200 m.) and **Wa** (200-1,000 m.).

In the east monsoon the air is extraordinarily dry on the lee side of the mountains, thus in the center and the northern part of the island.[78] It is true that no extensive meteorological observations have been made in Soemba, but at Koepang on nearby Timor a minimum relative humidity of the air of 14% has been

78. C. Braak, Het Climaat v. Ned.-Indië, II (1929), p. 476.

recorded, and of the 3 driest months an average daily minimum relative humidity of 45% existed. Since Koepang is located on the sea, the interior of Soemba would probably have still lower figures. No wonder then that "most trees lose their leaves" (see Fig. 87, page 247) "and brooks, creeks and many springs dry up. The nights in these dry months are very cool, sometimes cold. At times differences of 50° F are observed between day and night temperatures."[79]

Rainfall data are but scant (see Table 65).

Table 65

DISTRIBUTION OF RAINFALL DURING THE YEAR, ON SOEMBA[1]

Place	(Location)	Height above sea level (meters)	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year	Humid (wet) months	Arid (dry) months
Parona Beroro	Western coast	20	10	89	367	285	242	117	63	56	27	36	24	90	151	238	1696	6	4
Wai Mangoera	Western slope	350	11	134	422	447	370	249	143	100	55	68	45	175	132	316	2522	9	2
Karoeni	Northern slope	75	10	80	335	294	219	104	40	32	20	26	21	56	45	270	1462	5	7
Waikaboebak	Western interior	360	19	108	325	300	339	114	75	19	16	34	44	64	215	330	1875	6	4
Waingapoe	Northeastern coast	15	24	55	173	148	156	75	29	13	6	8	5	5	29	130	782	4	7
Melolo	East-northeast coast	10	19	54	151	156	171	75	42	30	12	12	3	6	31	116	807	4	7

1. J. Boerema, Kon. Magn. Meteor. Observ. Batavia, Verh. 24 (1931), p. 210.—The figures running over a number of years up to 1928 inclusive, for the three last mentioned stations in the table have been supplemented with the results of 1929 and 1930.

Even though there are only a few of these stations, it is evidently clear that in the west, against the slopes of the mountains, a decent amount of rain falls, especially in the west monsoon. Even the dry east monsoon is very moderate, taking into consideration the location of Soemba. The entire northern and northeastern coasts, however, have a long and fierce dry season, so that the soil cannot help drying out intensively every year. That to the south of the line connecting Waikaboebak and Waingapoe there is but one station, namely Melolo, on the east-northeast coast, is indeed to be regretted. Especially because a few rainfall stations in the far from unimportant mountainous region of volcanic products would perhaps provide interesting data.[80] So I am constrained to believe that in the regions of Lamboja and especially Massoe, localities must exist where the rainfall is still greater than at Wai Mangoera. But only the future can give us the facts. Meanwhile the kinds of soils which are found also indicate heavy rainfall.

Ways in Which Weathering Occurs and Resulting Soil Types

Since no descriptions of Soemba soils have yet been published, we will have to be content with sporadic observations in the literature cited above (page 245), supplemented by a few statements by administrative officers.

During a couple of short trips into the interior back of Waikelo and back of Waingapoe, I could of course obtain only very superficial impressions; combining these with the other data, we have the following sketch:

As parent rocks of the soil of Soemba the so-called marls come into the foreground. Presumably, however, these are not true marls, for they originated from marine deposited calcium carbonate of organic origin, mixed with more or less coarser or finer volcanic material. But thoroughly-weathered clay, such as large rivers carry out from continents or islands

79. Mem. v. Overg. afd. Soemba van Ass. res. C. E. Lanz (1919).

80. The Residency of Besoeki (Java) somewhat smaller than Soemba, but actually more important, has approximately 224 rainfall stations; and even Madoera, of only half the size, has 30 stations.

toward the sea, could not have been abundant during the time of the forming of these mixed marine sediments, because of the simple reason that at that time there was no extensive land surface which could have delivered such clay. These so-called marls will not give rise to clay simply through taking up of water again. From these materials clay can form only as the result of the weathering of the eruptives mixed with the lime. These deposits which are in the vicinity of the mountains of basic eruptive materials are obviously also more basic. But near to centers of more acid eruptions, and everywhere at considerable distances from the centers of eruption, because of the sorting by the wind (see pages 35 and 36), the materials are more acid in character. The eruptions of basic rocks are in the minority, while the acidic are far in the majority. This signifies, for soil formation, that the chances are very small that iron-rich, brown and red soils can develop from these marls, which thus should be called tuffaceous limestones or calcareous tuffs. Brown and red, iron-rich soils are only to be found near the centers of basic eruptions, which in the preceding sketch map are located in and around the bodies (1), (5), and (7). Locality (6), on the contrary, both on account of the parent rocks and because of the climate, is predestined for the making of black soil. This has been confirmed by experience. The entire arc of calcareous tuff, lying north and northeast of the tract of the eruptives, thus comprising more than half of the island, all has this same formation of blackearth. The more distinctly so, the farther away from the centers of eruption. Thus along the northeastern coast from Waingapoe toward Melolo and still farther. Where the parent rock is **(K + V.a)** and has but little tuff material in proportion to the $CaCO_3$ can be expressed by **tK**, the formula of the blackearth becomes: **tK--He.nvv.am (I-3)**. Closer to the mountains, with more tuff material in the rock the formula is: **(V.a + K)--He.nvv.am (I-3)** or in an extreme case **kT--He.nvv.am (I-3)**.

Along the road from Waikelo toward Karoeni the limestone, however, possess more **V.b.** originating from the Penoeboe mountain range, etc. and these materials make the land there more of a dark blackish brown: **(K + V.b)--He.Nr.ae (2-3)**. And there are of course places where, due to the deposits carried by one or another river in the past or at the present time, more **V.b** is concentrated in the lime, so that the limestone has already a reddish tint and the soil is also similarly affected. Such occurrences, however, are probably not of importance. Again at Karoeni (see Fig. 88, page 250) the soil itself, especially upon flat spots, is as black as soot.

If in the middle of the dry season, when many trees are bare (see Fig. 87), one goes out from Waingapoe toward the south and climbs up toward a high point, the great expanse of bare and dreary landscape is quite depressing (see Fig. 89, page 251 and Fig. 20). It even makes one wonder whether he is still really in the Netherlands Indies.[81] Everywhere the naked limestone rocks, grayish in color, project up sharply out of the dry grass, which is just about the only vegetation. Trees in numbers are almost entirely confined to the ravines, where the creeks for the greater part in this season are dry.

This is the region of strong wind erosion. Without erosion, black earth would obviously develop. In the rainy season this soil would perhaps offer reasonable resistance against sheet erosion because of its high plasticity and cohesive power. In the dry season this black earth cracks and breaks up to such a fine dust that the wind picks it up and carries it along. The coarser "air colluvium" is deposited in the valleys, (see pages 189, 190) and forms relatively productive black flats (see Figs. 90, 91, and 92, pages 251 and 252). In the long-continued east monsoon, however, these also dry out and crack deeply, so that even here the vegetation often cannot hold out. When the rains break, so that the rivers which had previously almost or entirely disappeared are in flood, then much soil again washes away as gray silt, for as a consequence of a high lime content the black earth is in the form of coarsely dispersed crumbs.

81. This was also the impression in the gathering of the Geol. Mijnb. Gen. in which Witkamp first exhibited the beautiful photographs, of which a number have been reproduced here.

Photo by Mohr

Fig. 88. Northwestern Soemba. Karoeni Mission station.--Flat foreground of black earth with lime concretions from tuffaceous marl; **tM--He.nvv.am.3** (Marl spread over the road!)--In the distance are hills with (toward Waikelo) transitions from black earth toward blackish brown: **tK--He.Nr.ae.3.**

Somewhat more toward the west and south where the drought is not so long, the soil in the erosion valleys remains sufficiently moist to allow certain trees to live and forest can hold its own (see Fig. 93, page 253).

The more southerly one goes, the earlier the tuff limestone presumably appeared above water, the older the landscape is, and the more it is incised by erosion (See Figs. 94 and 95, pages 253 and 254). Still more southerly, more than half way across the island from north to south, close to the mountainous land of Massoe, the duration and the intensity of the dry monsoon diminishes, the rains increase, and the proportion of eruptive material in the tuffaceous calcareous material also increases. These are all reasons for the increase of vegetation (see Fig. 96, page 254), so that finally the forest triumphs (see Fig. 97) on brown soils from volcanic material. Here the soil may answer to the formula: **V.b--Wa. (Nr to NN) ae.3.** Finally back over the divide, the east monsoon is rising and moist, and on the southern slopes of the volcanic mountains of andesite and basalt of more than 1,000 m. elevation it must rain as much in the east monsoon as in the west monsoon, as is shown in the small map (Fig. 6) for the Smeroe and the Idjen mountain chain (of Java). In this case the formula becomes a complete **V.b--Wa.NN.ae.3**, and the vegetation will be true tropical high forest (see Fig. 98, page 256). Dropping down toward the coast over volcanic country the soil continues a brown lixivium and the forest vegetation persists until close to the sea (see Fig. 99, page 256).

Going from Waingapoe westward, near Palendi-Medita, directly south of Soemba's northernmost point, under the calcareous material which becomes continually richer in tuff, eruptives appear in

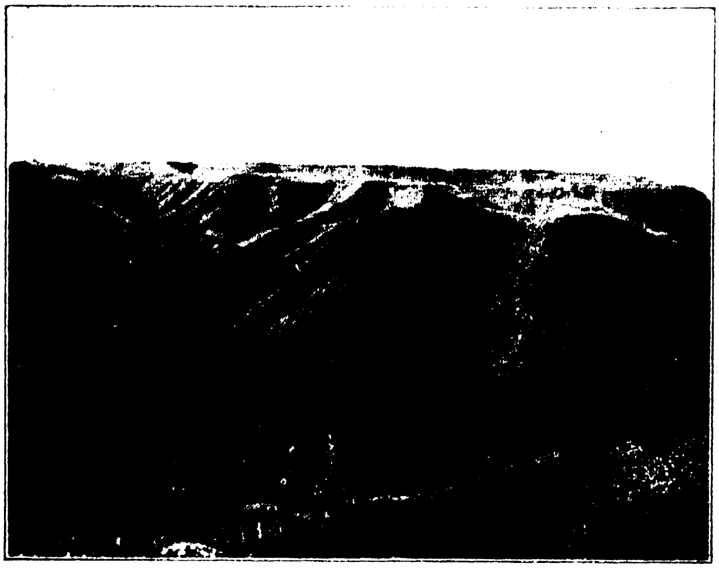

Photo by H. Witkamp

Fig. 89. Soemba. Looking toward the north out over the 380 m. terrace to the south of Merada Moendi.--Almost entirely bare because of drought. What little soil there is, is blackearth.

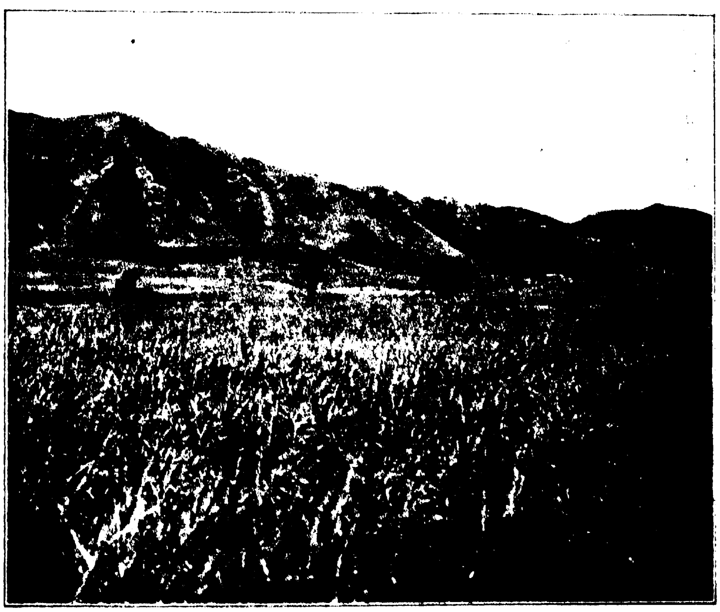

Photo by H. Witkamp

Fig. 90. Soemba. Slopes of Mt. Prai Madita eroded bare by water and wind. Kambera valley in the foreground, filled by material blown off and washed off from elsewhere.

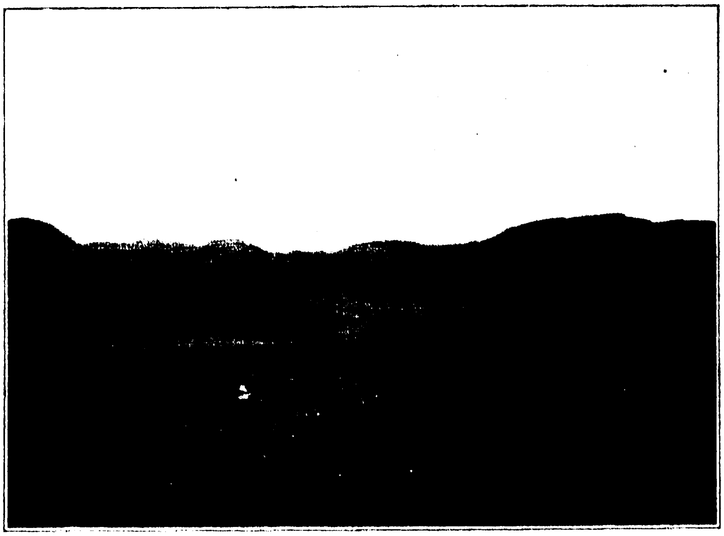

Photo by H. Witkamp

Fig. 91. Soemba.--Lake Wai Rindeh (550 m. above sea level), west from Waingapoe. The pond dries up in the east monsoon. Moreover, it is being gradually converted into land through the black earth being blown into and washed into it.

Photo by H. Witkamp

Fig. 92. Western Soemba. Plain east southeast from Wai Dindé; 440 m. above sea level with blackearth (?) on which are scattered limestone blocks. Strong horses are raised on the thin grass pasture. In the background (toward the west); Mt. Djagila.

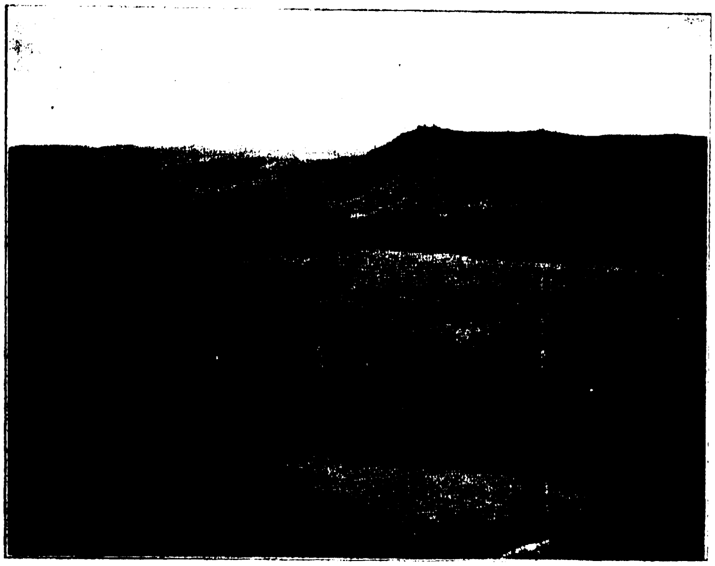

Photo by H. Witkamp

Fig. 93. Central Soembá. Palendi Medita. The poorly pervious ridges almost without soil and moisture, support only grass, while forest is everywhere in the erosional valleys.

Photo by H. Witkamp

Fig. 94. View of Massoe Bokoel. Southeastern Soemba.--Country strongly dissected. Some soil lies on the tops of the ridges and in the ravines; the slopes are eroded bare.

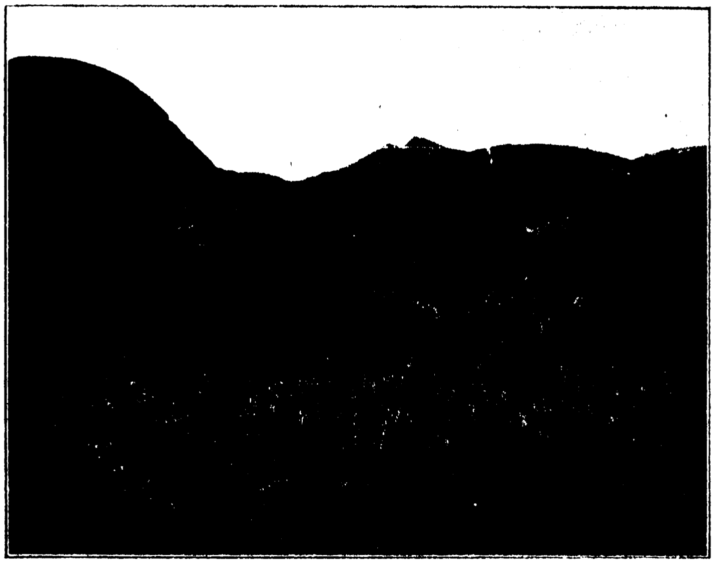

Photo by H. Witkamp

Fig. 95. Limestone landscape to the south of Meramoendi, Northeastern Soemba. Even in the valleys there are almost no trees.

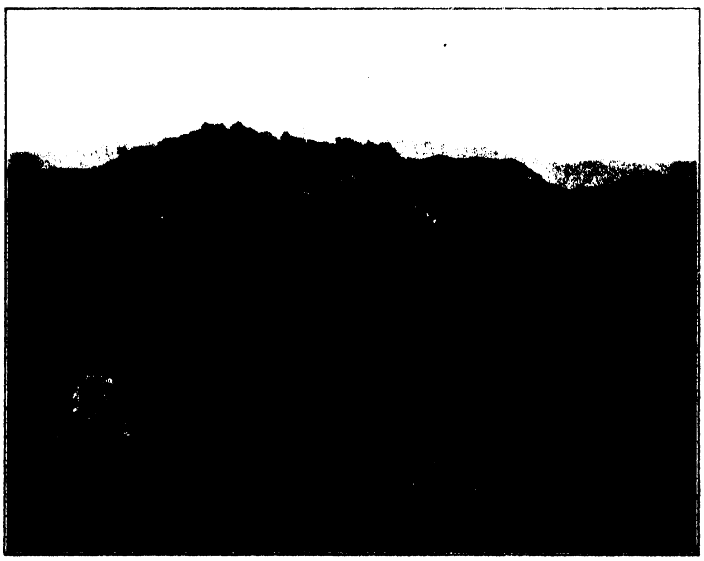

Photo by H. Witkamp

Fig. 96. The Massoe Mountain range Southeastern Soemba, from the north. Somewhat more vegetation, but still no continuous high forest.

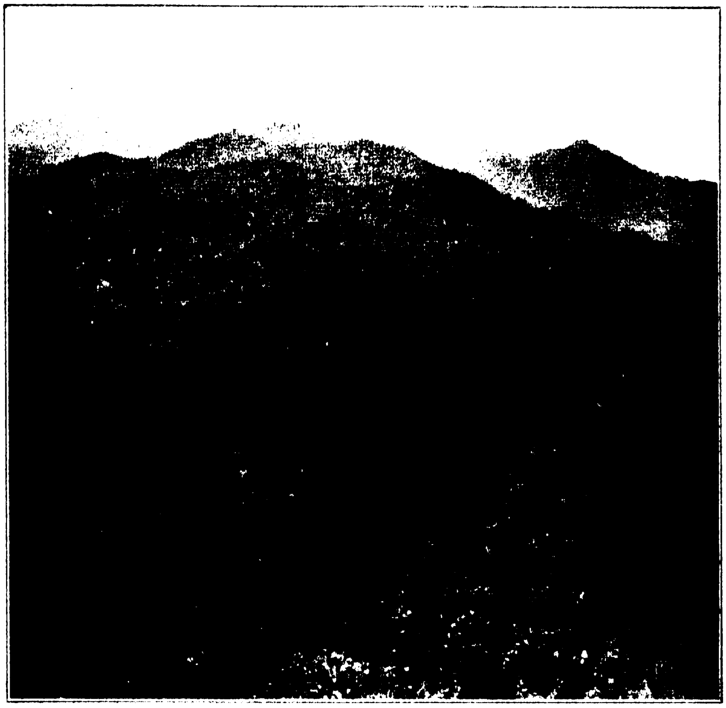

Photo by H. Witkamp

Fig. 97. Southeastern Soemba. Mountainous land from region 7 of the sketch, page 246. Mt. Wanggamati in the distance. In front of it Mt. Pokoel. Nearly closed forest, but no dense high forest.

compact form. Quartz porphyry (see Fig. 100, page 257) is the most abundant. The climate, however, is very dry, so that there cannot be much more vegetation than in the regions richer in lime lying more to the east.

Still farther west near the andesitic Mt. Penoeboe the climate becomes somewhat more moist, and where the eruptives project up through the calcareous tuff cover, the more intensive vegetation is clearly observable (Fig. 101, page 257).

In the south of the mountainous land of West Soemba and also against the western slopes of the mountains, of which the Djagila rises to over 900 m. elevation there is, just as to the south of the Massoe mountains, much rain during almost the entire year and therewith the fertility in general increases. Hence both because of the climate and because of the soil, it is not to be wondered at that there is much more cultivation in western and especially southwestern Soemba, and that the much more dense population practices the cultivation of lowland (irrigated) rice (see Fig. 102, page 258).

It goes without saying that the great diversity of the igneous rocks which appear in the southern half of Soemba is accompanied by distinct differences in the nature of the soil. But regarding these soil differences as yet insufficient data are available to permit going into this more closely.

Evaluation and Utilization of the Soils

Anyone who is not familiar with more than the northern and northeastern coastal regions of Soemba, must indeed have an impression of deplorable infertility. If, however, it be taken into consideration that from the northeast toward

Photo by H. Witkamp

Fig. 98. Southeastern Soemba. Massoe region; the southern slope of Mt. Kariki. Closed high forest which holds its own in an adequately humid climate. Soil: reddish brown **V.b.--Wa.NN.ae.3.**

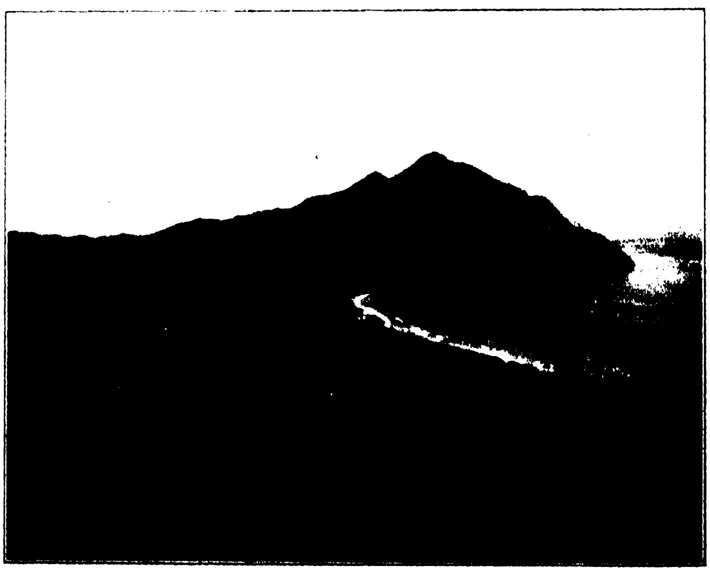

Photo by H. Witkamp

Fig. 99. Soemba's southern coast from Melanggoe out over Wahang bay and Mt. Kaboendoe Mawoa.—Where forest is lacking, it is because of deforestation.

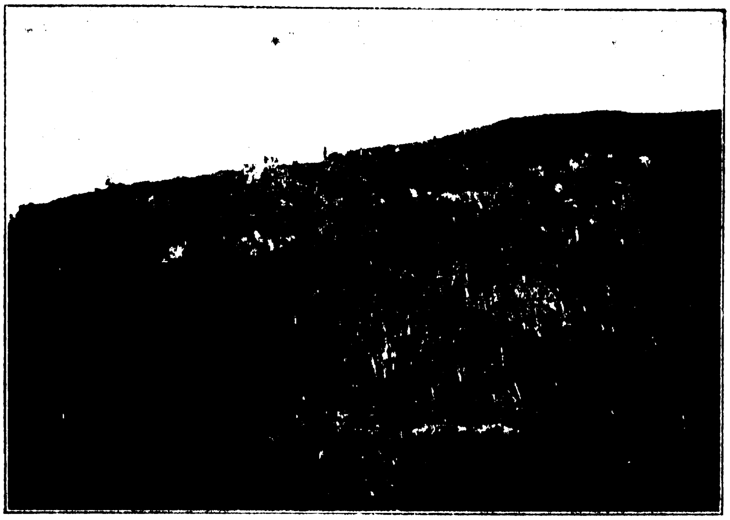

Photo by H. Witkamp

Fig. 100. Central Soemba 1 km. southeast from Palendi Medita.--Quartz porphyry hill with limestone lying upon it. (Region 6 of the sketch, page 246). Soil poor, shallow, subject to water and wind erosion. Vegetation at most poor savanna.

Photo by H. Witkamp

Fig. 101. Mt. Penoeboe, western Soemba from the east.--Where eruptives project up through the lime cover, there is more intensive vegetation and forest upon deeper soil.

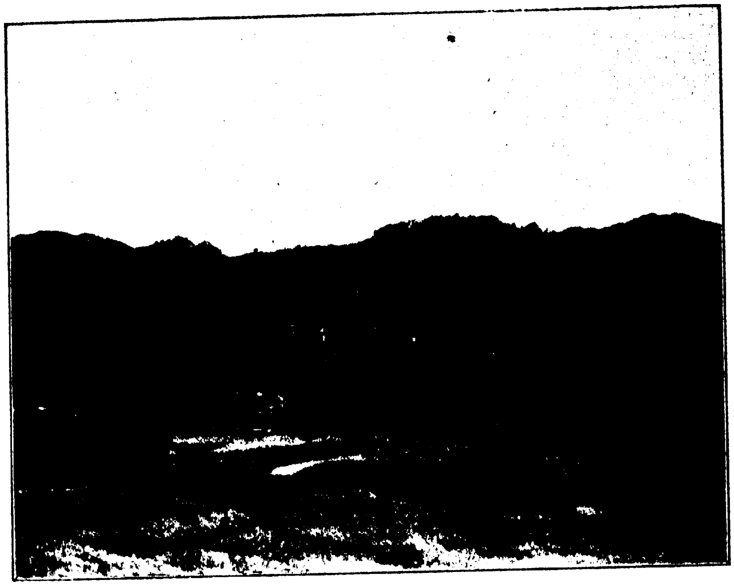

Photo by H. Witkamp

Fig. 102. The Lamboja valley, Southwestern Soemba, with behind it the hilly Soda ridge—To a great extent the soil has developed from eruptive rocks; climate humid enough for lowland rice cultivation.

the south west 1st the rainfall increases, and more particularly that the dry season more and more loses its fierceness; 2nd in the parent material more and more eruptives predominate which increase the fertility. Then we realize that on Soemba there are indeed places where almost every cultivated tropical crop can find favorable edaphic factors for development. It then becomes only a question as to whether these places are of sufficiently large area to make possible and profitable the cultivation of any particular crop.

As to the principal food crops, rice and maize, it should be stated that only in the west and south, but not in the south of Central Soemba (see Fig. 102 above) is there sufficient water for paddies. Consequently lowland rice fields are to be found only in the southwest. (In Lamboja and in the surrounding regions there are only a few, in Taboendoeng and Massoe only sporadically, though without doubt they could be extended there.[82] Of course maize also grows well in the abovementioned regions, but it is not planted as much as rice. Maize is, however, the main food crop in all other regions of Soemba, where neither paddy nor upland (unirrigated) rice culture is possible. And even maize does not grow everywhere. As has already been explained, on the bare marl or tuff limestone rocks there is insufficient soil to enable a full root system to develop, so that even in the rainy season no mature grain is to be obtained from maize on such soil. Only in a region of deeper soil is a crop possible and in the north and east such soil is found only in the bits of flat land in the river valleys (see Figs. 90, 91, and 101).

Crops which are well adapted are recommended for these heavy black lands. Besides upland (dry) rice and maize, beans

82. In this spirit also the Assistant Resident Cambier van Nooten wrote in his memorandum of giving over charge, Aug. 1928, p. 13 in which among others the environs of Tana Roöng (Massoe Karera) are mentioned as beautiful lands for irrigation.

and cotton are suitable. Especially, if the number of inhabitants increases, and as a result of the ultimate revival of export of copra, the use of coconuts as sources of fat and oil for the natives becomes precluded. Then as on Java, the inhabitants, will use more and more beans to make up their need for fats.

Formerly the natives cultivated cotton on Soemba and spun and wove the fiber at home. Later, because of the importation of cheap machine-made cotton yarn, cotton cultivation has retrogressed. The sorts of cotton grown were mostly those that live longer than one year. However, at some time or other cultivation of suitable annual cotton will be resumed, since certain lands on Soemba, because of soil and climate, are very well suited to this crop. Whether or not these soils are used for cotton is more an economic question than one of pedological or of technical agricultural nature.

As to kapok--in the course of time there may be expected an extension of its cultivation. The long and certain dry season is for kapok, as for cotton, of great significance. Moreover the soil is certainly fitted for kapok especially in the south where much of it is brown and red lixivium.

In the higher southerly stretches up against the mountains of eruptive rocks, where the land is decently fertile because of an annual dry season, such as is desirable for arabic coffee, various good places are to be found where its cultivation is possible. Coffee is already being planted and an extension of the plantings is still possible, provided that the plantings are not carried down too low, nor into too dry nor too moist localities. As long as coffee remains on good land, success is certainly to be expected from it.

As to tea, of which it is said in Java that this shrub cannot endure more than 100 days drought (perhaps with the one exception that if at the same time the weather is quite cold), the chances on Soemba are very small. This is because of the climate and because of the very limited, suitable, high, not too steep spots in the mountains.

Keeping in mind the soil moisture requirements, in the low lands the cultivation of various fruits can certainly be extended.

In the last decades many more coconuts have been planted than previously. Especially in the two relatively moist Kodi regions the cultivation of this crop has a good future,[83] as is also the case in Lamboja (see Fig. 102) and in Wanokaka on the land sloping to the south. In the north the palmyra palm (Borassus flabellifer), which is much better able to resist drought, must uphold the honor of the palms in supplying many useful things for the native household.

* * * * *

Surveying the whole, we are convinced that the political quiet insured by the Netherlands Indies Government has opened up for Soemba a number of agricultural possibilities which previously practically did not exist. On arriving at Waingapoe on Soembà, the island, as concerns soil and climate, is seen at its worst. The farther one goes from there into the interior of the island, to the south as well as toward the west, the better the conditions become. But it will be the task of the authorities to direct development along the right lines. For example, they should see that on and around the high mountain tops (which still are not excessively high, only 900-1,200 m.) the forests are maintained and even extended by planting. This is to insure that the lower land can continue to obtain as much irrigation water from the rivers during as long a season as possible. Money expended for this purpose is better spent than if it were paid out for repairing of bridges and roads, which must be done following floods. These floods destroy much of the arable land in the low valleys which after all is not abundant.[84]

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83. See Mem. v. Overg. ass.-res. Soemba, C. E. Lanz (Aug. 1919), p. 15.
84. The same, Mem. v. Overg., p. 51.

TIMOR

Soil-Forming Rocks

Few islands of our Archipelago exhibit within such a relatively small compass such a diversity of rocks. The reason for this is the complicated geological structure of this island. This is not the place to go into the extremely interesting geology of Timor. For this the reader will have to refer to the comprehensive literature[85] regarding the subject. Brouwer investigated and described a long list[86] of rocks of East Netherlands Timor, collected in the course of different expeditions. If material of this sort were available from the whole island,[87] the list would become still much longer. However, by no means are all these rocks "soil forming" in the sense employed in this book. Of course they all do contribute something, but many occupy only relatively small areas so that they do not deserve any separate discussion. As to these, some few indications will have to suffice.

If a line is drawn from the bay of Koepang out in the direction of the longitudinal axis of Timor, thus toward the east northeast, over Tjamplong and Soë, along the upper course of the Noil Benain and on further into Portuguese territory, then for the greater part of its length this line runs through relatively low land. South of this lowland lies high mountainous land, and north from it much higher mountainous land. Thus Timor may be considered as roughly divided into three strips or zones.

Within the northern strip, the largest of the three, stand the highest mountains, of which we may mention particularly Mt. Moetis (2,365 m.), Lakaän (1,580 m.), the Mollo mountains and a couple of others of crystalline schists. The schists, however, chemically and mineralogically are not so rich in silicic acid as, for example, those on Sumatra or Bangka and Billiton. They are relatively poor in quartz and mica, but they are rich in all kinds of feldspars and especially amphibole. Besides, they possess a number of other minerals, the chief of which are epidote minerals, such as zoesite. In addition, titanite, pyrite, chlorite and sericite, chalcedony, calcite occur. The last is sometimes scattered through the rock, sometimes in the form of separate veins or thick strata.

A large part of this northern strip is further occupied by formations of the Permian and Mesozoic; especially in the form of marine clay (with fossils) or grayish clay deposited in the deep sea. As rocks these are, of course, more or less compact claystones, but exposed to the atmosphere they obviously take up water, disintegrate and again become clay. Further, there also belong to this formation the following: former shallow sea and coastal sediments of very variable grain size (Flysch facies). Also reddish, gray and white, hard marls, layers of limestone and more or less isolated limestone rocks ("fatoes" which, nevertheless, do not appear to consist exclusively of limestone) are present.

This northern strip is also rich in eruptives mutually very divergent both in structure and composition. Of pretertiary age, for example, are peridotites, serpentines, gabbro, diabase, melaphrye, diorite and similar more or less basic rocks. Relatively close to the northeastern coast lies a strip which runs from Mosoe in the west, almost to Atapoepoe in which are also younger, namely Tertiary eruptives, beginning with basalts and andesites, and then grading via dacites to more acid rocks, such as trachyte, liparite and rhyolite, though the last are very much in the minority. These eruptives remind one of those which have been found in South Soemba.

Still younger eruptives do not occur in Timor; for there are no active volcanoes.

No marine deposits of either Tertiary or Quaternary time are found in the northern strip; neither are there any in the lower central strip nor in the southwest of the southeastern strip. Apparently

85. In the first place according to: H. A. Brouwer, Geolog. Overzicht van het O.-gedeelte van den O.-Ind. Archipel., Jb. Mijnw. N. I., 46 (1917), Verh. II, p. 145-452. Therein one finds on pp. 147-162 a long bibliography. For Timor the publications of Verbeek, Wanner, Molengraaff and Brouwer which are listed are apparently the most important.

86. H. A. Brouwer, Gesteenten van Oost-Nederlandsch-Timor, Jb. Mijnw. N. I., 45 (1916), Verh. I, p. 71.

87. Obviously we will not consider Portuguese-Timor.

there was a time before the present and in the later Tertiary when all of Timor lay lower, and especially the central strip which thus formed a quite deep sea channel, perhaps even 1,000 to 1,500 m. deep. Only parts (for example the Salomon Müller mountains) of the southeastern strip were not submerged. Of the northwestern strip, however, at least the backbone of it for the greater part remained above the sea. During this time much calcium carbonate could accumulate in the sea in the central strip. In the center it accumulated as Foraminifera lime, toward the sides however it was mixed with terrigenous sediments, clay, sand, and boulders. Where the water was clear it accumulated as coral. From that time on Timor began to rise, a movement which possibly still continues today. The rising has, however, been unequal in time and place. Probably it began slowly over the whole island; thereafter more rapidly, and especially in the central strip. It would be interesting by means of very accurate determinations of elevation of fixed points to see if in the course of 10 or 25 years such differential movement is continuing; but this topic falls outside the scope of the present book.

Here, in agreement with this geological history which, it is true, has been presented in inverse direction, it is only necessary to state: 1st that the thickest Tertiary and Quaternary deposits are found in the middle strip, 2nd that not alone does the thickness decrease toward the northwest and southeast, but also land sediments are more and more mixed through them in the northwest rather than in the southeast. This is true because the land mass lying to the northwest was of greater volume and surface. In many places, especially in the southwest corner of the southeastern strip, the surface covering is rather thin so that, in very many places, the older Permian formation protrudes through it.

In other, higher and more easterly lying parts of the southeastern strip, the older Permian lies quite exposed and entirely free from any younger covering. All kinds of outcrops of basic eruptives are also found in this region as in the northwestern strip, but in so far as is now known there are neither Neogene eruptives nor older crystalline schists; at most there is a little Eogene.

Analyses have been made of a number of rocks of Timor. These have been collected and are presented in Table 66, pages 262 and 263. These analyses should not be considered an adequate survey but at most just a few selected from a much larger number. However, the divergent values can now give an impression of what Timor offers in this field.

The rocks are not geographically arranged, but rather are in groups and within groups are placed according to their silicic acid content. First a couple of very acid rocks, rich in quartz. These, and the following group of rhyolite and trachytes show that although in surface area they occupy but a limited place, yet on Timor similar acid rocks do occur. Then there follow a number of more basic plutonic rocks, and thereafter a group of amphibole-rich schists, which have perhaps originated through metamorphosis from rocks of the former group. A serpentine is placed adjacent to these. Finally there follow a number of basic eruptive rocks.

As may be seen, the SiO_2 content varies from about 80% to about 40%,--indeed a wide range. Apart from serpentine and marl the following components also vary: Al_2O_3 between 10 and 20%, the iron oxides between 1.5 and 13%, magnesia between 0.5 and 7.5%, CaO between 0.5 and a little more than 13%, soda between 1 and 5.5%, potash between 1/3 and close to 8%. Unfortunately phosphorus was not always determined; but the few figures available vary from 0 to 0.66% P_2O_5, which is a fairly important range. It is also striking that the acid rhyolite contains no phosphorus, while the basalts give sizeable amounts.

Finally it may be stated that Wichmann recorded (l. c., p. 122) an analysis of a calcareous chalcedony-sandstone with 13% carbonates, while of the 87% remaining 80% is SiO_2, 2.5% Al_2O_3 and the rest is Fe_2O_3, MgO and water. On the other hand the calcareous marl No. 196 from the river Noil Sani (l. c., p. 124) contains 78.5% carbonate, while of the remaining 21.5% there was but 13% SiO_2, besides 5.5% Al_2O_3 and the rest 1% Fe_2O_3 and 1.5% H_2O. As to the marl, again it is a pity that phosphorus was not determined.

Table 66

ANALYSES OF SOME ROCKS OF TIMOR

Name of the rock	Strongly silicified rock	Granite porphyrytic Quartz porphyry	Alkali-rhyolite	Alkali-trachyte	Alkali-trachyte	Alkali-trachyte	Quartz augite-Amphibole-diorite	Quartz-diorite	Quartz diabase	Diabase (vitreous)
Place where collected	Top Fatoe Nainaban	Between Atapoepoe and Wehor	Noil Manoemea	Between Toenbaba and Haumeni	Fatoe Sanan	Fatoe Menasse	Near the Somoholle	Weiro valley near Atapoepoe	Weiro waterfall near Atapoepoe	Near Wehor south of Atapoepoe
Number.....	III 365	III 873	III 288	II 320	II 630	III 637	II 193	II 73	II 56	III 867
Analyzed by	PISANI	PISANI	MORLEY	PISANI	PISANI	PISANI	PISANI	PISANI	PISANI	PISANI
SiO_2	81.70	77.10	70.76	65.10	62.10	60.80	60.35	55.31	53.31	48.20
Al_2O_3	10.15	12.40	10.16	14.10	17.60	19.60	12.50	16.90	14.70	19.33
Fe_2O_3	0.69	0.61	7.00	2.70	4.10	2.81	5.35	2.10	6.40	2.19
FeO	0.57	0.84	0.63	1.71	---	---	3.57	6.75	4.50	8.61
MnO			0.16		0.20				---	
MgO	0.52	1.40	0.49	2.45	0.91	0.77	3.10	4.95	4.17	4.22
CaO	0.39	0.51	0.65	1.55	1.81	1.03	3.35	8.81	7.42	13.24
Na_2O	2.45	2.77	5.53	5.45	5.31	3.95	5.30	2.97	2.75	3.44
K_2O	3.38	2.15	2.57	4.92	6.35	7.85	0.79	0.49	0.48	0.36
H_2O + ...			0.88							
	[1] (0.65)	(1.60)		(2.10)	(1.70)	(4.00)	(3.00)	(1.20)	(4.70)	(0.74)
H_2O −			0.57							
TiO_2	0.08	0.06	0.49	0.39	0.27	---	2.59	1.34	1.69	
P_2O_5			0							
Residue[2] ..			0.27							
Total	100.58	99.44	100.16	100.47	100.35	100.81	99.90	100.82	100.12	100.33
AUTHOR	Br.[3]	Br.	Br.	Br.	Br.	Br.	Br.	Br.	Br.	Br.
Page	136	158	133	147	150	141	88	77	230	220

1. The figures ( ) signify loss on ignition.
2. Under this are included: CO_2--CuO--SO_3--Cl--F--S--BaO--SrO.
3. H. A. Brouwer, Gesteenten van Timor, Jb. Mijnw. N. O. I., 45 (1916), Verh. I, pp. 71-260.

Of the Permian deposits lying on the surface over great areas, not a single analysis has been made. This is indeed to be regretted, because these materials are certainly a parent material for soil formation. Judging by the analyses of deep sea desposits from elsewhere in the world[88] it is by no means improbable that specially the P content is considerable in comparison with that of many magmatic rocks.

Climate

As contrasted with Soemba, with its longitudinal axis practically perpendicular to the direction of the east monsoon, Timor lies in the trade wind belt. And moreover since the mountains may be considered as divided into the above-mentioned three strips, one cannot be surprised that extreme climatic conditions

88. Compare the analyses of marine sediments in: F. W. Clarke, Data of geochemistry, 4th Ed. (1920), pp. 508-510.

Table 66 (continued)

ANALYSES OF SOME ROCKS OF TIMOR

Epidote sericite chlorite schist	Plagioclase amphibolite	Hornblende schist	Bronzite Serpentine	Fatoe-Kedoewa rock	Lakmite (boundary basalt and andesite)	Shonkinite (with plagioclase)	Shonkinite (with plagioclase	Foyaite	Plagioclase basalt (weathered)
Near Fatoe Neukatella	From the Noil Besi Moetis Region	From the Noil Bessy near Fatoe Infeni	Oisain river Amarassi	Fatoe Kedoewa	Pass between Lahhoeroes and Weloelik	Noil Nimassi between Haoemeni and Kaonèke	Noil Kolkoil between Pariti and Noeataoes	Noil Banatette near Pariti	From the river Noil Noni
72	IV 407	214	82	I 520	VI 8	II 352 (a)	II 352 (b)	64	173
PUFAHL	PISANI	PUFAHL	PUFAHL	MORLEY	PISANI	PISANI	PISANI	PUFAHL	PUFAHL
57.96	56.70	48.62	38.81	51.74	51.51	45.70	44.95	44.63	43.70
17.91	15.42	15.49	1.14	15.46	16.90	15.40	14.60	13.77	14.98
3.82	0.82	6.32	5.80	4.39	4.40	2.75	3.70	7.30	5.38
4.59	5.95	4.92	2.10	4.39	3.55	5.67	7.20	5.60	5.44
0.12	—	0.09	trace	0.26		0.26	---	0.08	0.06
2.82	5.45	7.13	35.91	5.73	2.74	7.55	6.72	4.47	7.45
3.36	8.65	10.36	0.32	10.07	7.95	9.02	8.15	7.96	9.64
1.10	3.40	3.92	0.12	1.54	3.39	3.12	3.62	4.20	3.02
1.48	0.34	0.46	trace	0.64	2.30	3.22	1.59	2.65	2.38
				2.60					
5.85	(1.30)	1.52	14.87		(3.80)	(3.90)	(4.20)	4.04	5.27
				2.05					
0.64	1.54	1.52	0.16	0.73	3.26	3.46	4.15	4.25	2.15
0.17		0.26	0.03	0.40	---	0.26	0.19	0.09	0.66
				0.28			1.55	1.34	0.11
99.87	99.57	100.61	99.92	100.28	99.80	100.05	100.62	100.43	100.24
W.[4]	Br.	W.	W.	Br.	Br.	Br.	Br.	W.	W.
94	237	137	109	205	190	93	96	85	128

4. A. Wichmann, Gesteine von Timor, Samml. d. Geol. R. Mus. Leiden, Ie Serie, 2e Bd. (1882-'87), pp. 1-172.

are to be found on this island. That the conditions are extreme appears clearly in the figures (Table 67, page 264).

Although there is a certain amount of variation in the quantity, the months from December to March inclusive always constitute the rainy season, while the months August and September are dry although occasionally a shower will fall here or there. The other 6 months show very variable rainfall figures.

L. J. C. Van Es, Jr., who worked on Timor for a long time as a mining engineer, divides the land climatically into thirds. Regions where it rains three months of the year; regions where it rains six months, and those where it rains nine months.[89] This estimation comes pretty close to the results of the observations, if they are considered year by year.

In the west monsoon Koepang receives the full broadside, but in the east

89. Quoted by: Alb. C. Kruyt, Verslag, reis door Timor, T. Aardr. Gen., 38 (1921), p. 776.

Table 67

DISTRIBUTION OF RAINFALL DURING THE YEAR ON TIMOR[1]

Place	Number of years of observations	Elevation above the sea (meters)	Rainy days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year	Humid (wet) months	Arid (dry) months
Koepang........	52	15	69	385	366	221	66	27	8	5	3	2	18	88	247	1436*	4	6
Soë............	8	1000	86	251	202	302	111	35	24	23	5	4	17	99	292	1365*	5	6
Niki-Niki......	12	670	108	258	268	244	111	108	63	42	12	3	33	87	235	1464	6	4
Kapan..........	6	1000	131	204	262	260	220	145	134	120	48	7	124	236	252	2012	10	2
Noiltoko.......	8	550	104	195	244	231	161	89	80	67	11	11	74	137	231	1531*	6	2
Kefannanoe.....	7	1000	62	216	153*	170	62	52	11	6	0	1	17	104	157	949*	5	6
Soekabihanava (Besikama)..	15	9	84	209	155	187	147	224	93	82	14	8	17	64	196	1396*	6	3
Haliloelik.....	2	400	64	110	214	255	42	13	0	0	0	1	107	54	286	1082*	5	7
Atamboea.......	11	325	79	278	257	276	79	25	25	11	7	37	65	140	212	1412*	5	5
Atapoepoe......	15	2	63	292	258	159	58	36	7	4	4	2	16	89	160	1085	4	7
Lahoeroes......	2	600	90	242	213	370	13	3	22	0	0	0	59	44	335	1301*	4	8

1. J. Boerema, Verh. Kon. Magn. Meteor. Observ. Batavia, No. 24, p. 210. The stations with a * have the figures for the years 1929 and 1930 corrected and supplemented.

monsoon the town lies in the lee behind a mountain more than 500 m. high to the southeast. It is no wonder that the descending wind is dry, and that in many a year there are 8 dry months in place of 6. --While it is true that Soë lies on the highest point of the central strip between the mountainous Amanoeban region (southeast) and that of Mollo (north), yet apparently Soë's position is such that in the southeast monsoon Amanoeban takes out all the rain. In spite of its elevation Soë is very dry for 6 months. Niki Niki lies east of Soë and hence at the beginning of the rainy season gets somewhat more rain. Kapan lies favorable for rising air currents from April to July, as also in October and November. Hence the dry season is not very pronounced. Kefannanoe however is reached by the southeast monsoon only after this has swept over the especially dry low hilly country of Noë Moeti and Neno Metan. Hence the dry season here is very pronounced indeed. Noiltoko is in this respect a connecting link between Kapan and Kefannanoe.--Besikama lies close to the sea, the rainy time continues somewhat longer, but is less intense. Here, just as at Kefannanoe (with respect to the West monsoon in the lee behind the 1,200 to 1,500 m. high boundary mountain range with Oeikoesi), there is but one month with more than 200 mm. rainfall. Haliloelik lies in the depression, with higher mountains to the northwest and southeast; hence the strong east monsoon drought.--Atamboea is already on the slope toward the north; Atapoepoe lies on the coast. Though the 4 rainy months may produce much rain, the east monsoon is cork dry. Even at Lahoeroes, which is at an elevation, the drought is severe since the place lies so directly behind the high Lakaän mountain range.

Ways in Which Weathering Occurs and Resulting Soil Types

Given the above-described monsoon conditions, it is clear that places on Timor where the whole year through it rains enough to make possible a continuously descending movement of water in the soil, (NN) will be very great exceptions. Such places are, for example, near Nenas, at more than 1,200 m. elevation against the south southwest slope of Mt. Moetis, or near Masedemoe located at 1,000 m. against the southwest slope of Mt. Lakaän. Elsewhere, Timor falls under either the symbol **Nr** (on pervious material) or **n.vv** (on more clayey, poorly pervious material). A few small, low flat bodies of soil may have **ns** or even **N.S.**

Which is found the most on Timor? nicely pervious or poorly pervious soil material?--As to how difficult it is, on

basis of the still inadequate data now available to give a satisfactory answer, will appear from a closer consideration of the above-mentioned Permian deposits which are spread over a large area. The red deep sea silt can be hardly anything else than very fine-grained. On this parent material we can expect nothing else than heavy, impervious soils, although the iron should make the soil somewhat crumbly and looser. This would especially be true if under n.vv conditions the dehydrated iron oxides go into solution and then precipitate as iron hydroxides. This increases the permeability. If the ground possesses lime in the form of fossils, then this material increases the permeability so that the water movement goes more toward N.r. Thus, the ground remains red or it can become red. A couple of soils of Timor, collected by Jonker (1916)[90] belong here. These soils were described by him as follows:

No. 700.[91] "Surface soil near the village of Fatoe Ino, approximately 3 km. from Niki-Niki, is a dark red, light clay. The thickness of the soil layer is approximately 30 cm. It is residual, having weathered from Permian crinoid chalk. The vertical layers were originally red, but are now bleached. The land is approximately 570 m. above sea level. It is not used for growing crops, but is covered with grass." This soil is indeed dark red and bleached in flecks to a dingy gray, but when was it bleached? This is an open question which cannot be answered without closer local study. This soil is "sand"-containing in so far as calcareous sand, besides quartz, still remains in it in the form of fine and very fine sand, as well as silt. The "clay" is thus really a fine sandy loam. It is light, since the high lime content flocculates the colloids present. That the soil layer is but 30 cm. thick is to be laid to the double erosion; water erosion or sheet erosion in the rainy season, and wind erosion in the dry time (compare page 190).

No. 701. "Soil of village Bitono near Oilolok camp, 420 m. above sea level, on a complex of flat hills. Dark red, light clay, lying on marly limestone, originally grayish green, weathered red on the surface. Ammonite chalk, Permian. Growing only grass."

Actually this soil also is no clay, but a sandy loam. It is light for the same reasons that the previous one was light. The clay fraction is only 22%, silt and coarse silt 29%, and the sand is 49%.[92] It is calcareous and rather rich in iron. The formula runs: mK--Wa.Nr.ae.2, for the ground is fairly pervious. It is easy to understand that in the dry time there is no water for vegetation. Hence grass grows in the rainy season, but it dries up after the rainy season.

Whenever the Permian deposits possess much coarser material such as silt-sand, sand and even gravel and stones (for example the above already mentioned "Flysch") we can expect pervious soil on them. This is especially true if the chief constituents are quartz and iron-rich minerals. If however, there are, besides lime, admixtures in it such as fine, iron-poor loam and clay, then the weathering clay becomes a true clay, heavy and impervious. Then the soil isn't red but black. That is the case at Koepang. However, seldom does one find deep soil profiles on the hills, since the high lime content makes this land friable and granular and thus very susceptible to wind erosion (see Fig. 103, page 266).

Chemically these soil types from marine deposits are interesting, since they possess so much phosphorus, as has already been touched upon above (page 262).

Clark[93] records a P_2O_5 content of 0.30% as the average of 51 analyses of "red clay," a red deep sea silt. In addition he refers to the following analyses (Table 68, page 266) by Brasier.[94]

Even though these figures for $Ca_3P_2O_8$ be recalculated into P_2O_5 (the latter being 45.8% of the former), the

90. These notes by C.H. van Harreveld-Lako and O. Arrhenius are included in: Grondonderzoekingen van de Buitenbezittingen, Arch. Suikerind. Ned.-Indië (1927), Meded. No. 18, p. 720-722.

91. Numbers are those of the Proefstation Java Suiker-Industrie.

92. L. c., p. 722.

93. F. W. Clarke, Data of geochemistry, U. S. Geol. Survey, Bull. 616, 3rd Edition, p. 513.

94. Clarke, l. c., p. 508.

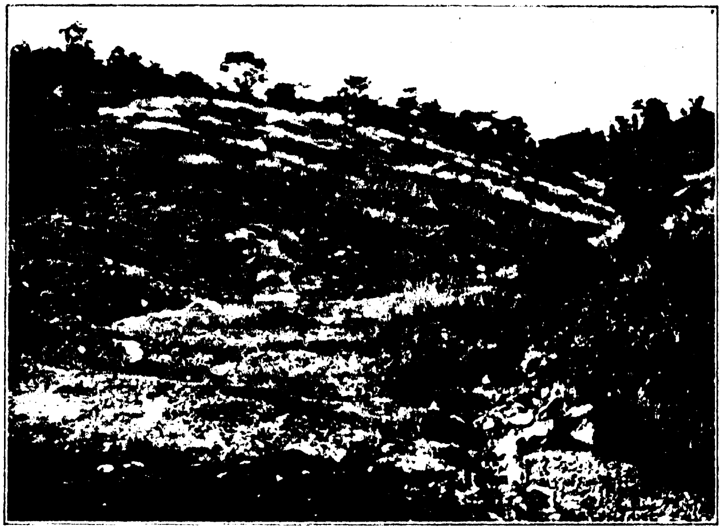


Photo by Lorentz Expedition 1911

Fig. 103. Southwestern Timor. Along the Koepang-Pinkassi road. A spur of the Ajer Mati. Blackearth with limestone gravel.--Characteristic savanna vegetation with umbrella shaped trees. (See page 273.)

quantities of phosphoric acid in the Radiolarian ooze, the Globigerina ooze and the Pteropod ooze are still high. The diatomaceous ooze is less rich, and the red deep sea clay by far the poorest.

Table 68

	$CaCO_3$	$Ca_3P_2O_8$	Average Depth
Red clay	0.92 %	0.19 %	about 3000 fathoms
Radiolarian ooze..................	3.89 "	1.39 "	" 3000 "
Diatom ooze	19.29 "	0.41 "	" 1500 "
Globigerina ooze (poor in lime)....	37.51 "	2.80 "	" 2000 "
Globigerina ooze (rich in lime)....	92.54 "	0.90 "	" 2000 "
Pteropod ooze......................	82.66 "	2.44 "	" 1000 "

The analyses made at the Experiment station for the Java Sugar Industry[95] are entirely in agreement with these:

"No. 697 (and 698). Surface (and sub-) soil near village Baoen, Amarassi (southeast of Koepang), from a flat part of the hills at about 400 m. elevation above the sea. Slightly cohesive black soil with much lime, lying on Pliocene globigerina limestone and coral limestone, and originating from it through weathering: thickness of the weathering layer about 40 cm. Thickness of the lime layer only a few m."

This land has an extraordinarily high phosphorus content, namely 0.445% P_2O_5 soluble in HCl, of which 0.379% is soluble in citric acid.

In contrast with this soil is the following: "No. 702. Soil of village Atamboea, about 1 1/2 km. from the Talauk River, which has carried out this material from the surrounding hills consisting of lime and volcanic tuff of Permian age. The ground is very deep and lies at about 300 m.

95. L. c., p. 722.

above the sea. Extensive grass plains with very high grass, maize and rice. This land contains very little phosphorus." The P_2O_5 content is 0.025% soluble in HCl and 0.003% in citric acid.

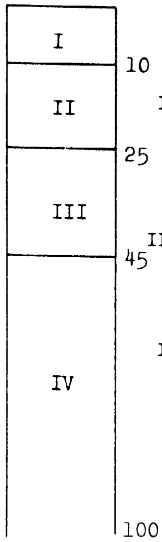
Regarding the locality where this sample was collected Verbeek[96] says: "It is a Quaternary lake deposit," formed "by the large river Talau" and others. The underlying rock is sandstone. "The plain is surrounded on all sides by hills, on the northern side by serpentine, on the southern side mostly by Tertiary marls,.... Through successive erosion of the Quaternary lake desposits" "the Talau river" formed "a series of seven terraces," from 283 m. above sea level to 330 meters. The soil No. 702 mentioned before is thus apparently quite well drained and leached out. In a conglomerate in place besides massive limestone, Verbeek established quartz porphyry (see the above collected list of rock analyses) and serpentine. Without doubt this explains the low phosphorus content.

Apart from that, this soil is called by Jonker "yellowish brown and light," a yellowish gray sandy loam soil, free from $CaCO_3$. But because of its sand and silt content it is moderately pervious.

Except for the few investigations of the Experiment Station at Pasoeroean, I have not been able to find any further analyses of Timor soils. The vague considerations given here show the need for more figures.

Although the necessary figures are lacking, we can borrow from a report of Timor, by the agricultural adviser J. Straub[97] the following, which in itself is quite worthy of mention.

Along the road from Koepang toward Baoeng "only lime formations were observed, along with the weathering products from them--black earth and red laterized earth." If the soil is very permeable, weathering of type **He.Nr.ae** is possible, and with laterization would develop the red color. Near Boerain for example the profile below was measured (scale 1:10) and sampled:



I = Black, sticky surface soil, (2.5 year coffee on it, doing well).

II = Still more sticky, heavier than horizon I; black with a reddish tint.

III = Reddish, crumbly, but almost more sticky than II.

IV = Loose material, hardly sticky at all, dark yellowish brown (moist); becomes light yellowish brown when dried in the air. Moist to 1 m. depth.

"Horizon I is pervious, while II and III show poor internal drainage. Layer IV is well drained." Since that is so, then it is conceivable that in the transition from III to IV the conditions **Nr.ae** prevail and a red color comes in. The heavy surface soil above the layers II and III which hold the water a long time, however, is subjected to **n.vv.am** conditions and can as a consequence become black.

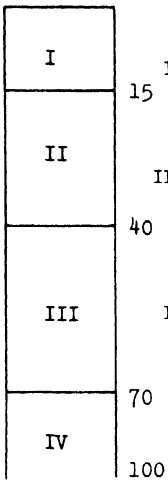
One other profile, No. 13, measured near Baoeng, exhibits a dry surface soil of 10 cm. black, specked with white points (of lime). Below that are 45 cm. of blackearth, with lime concretions. And then just below that is the parent rock (limestone).

Even though these two blackearths lay at about 450 m. elevation, others were found at greater elevations farther northeast. These are: No. 8, near Oiboeboek (in Mollo) at 1,000 m. elevation--No. 11 near Lo-el or Loil (in Insana) at 600 m. elevation and No. 12 near Fatoehauk (in Insana) at 650 m. elevation.

Below is a description of the profile at location No. 11:

96. R. D. M. Verbeek, Molukkenverslag (1908), p. 347-348.

97. Extract from the report of the agricultural adviser 1st class of the district Bali and Lombok, on the occasion of a visit to the island of Timor (Netherland's portion)--June/September, 1930.



I = cultivated soil, loose, black.

II = black, more dense, water holding.

III = padas layer, not especially distinct; a little yellowish coloring.

IV = black, sticky soil, mixed with limestone (concretions), continues to 1 m. depth (and deeper).

The rainfall will be about like that of Kefannanoe; hence having a dry monsoon. What layer III really is, cannot be made out from this scanty description.

If it is true that these blackearths agree in type with those of southwestern Timor, then this type is also represented by No. 697 of the Experiment of the Java Sugar Industry (see page 264) and the statement by Brink (pages 170-172) cannot then be maintained as generally applicable. For Java it may be true that blackearths--He.nvv.am do not occur above 200 m. elevation, but for Timor this rule does not hold good.

Although very little was recorded about the horizons, without doubt profiles Nos. 9 and 10 are interesting. The sampling sites lie in the Miomaffo region, near Naipèsoe, at 1,200 m. elevation and near Ebang at 1,500 m. elevation, in coffee plantations. Regarding No. 9 it is stated:

I = 0-20 or 25 cm. Weathered, reddish black cultivated soil, dry.

II = 20 or 25 cm. to 55 or 60 cm. Padas layer (the kind of "padas" is not recorded.

III = 55 or 60 cm. to 100 cm. white loam layer, which is uniform down to 1 m. depth (and farther ?).

The layers II and III are moist, and sticky with ground water at about 4 m. depth.

Profile No. 10 is:

I = 0-15 cm. Surface layer. Field strewn with stones (Parent rock? or iron concretions?).

II = 15-45 cm. Padas layer, as in No. 9.

III = 45-100 cm. White loam, as in No. 9.

* * * * *

In the Netherlands Indies "padas" is the term applied to any hardening of a concretionary nature. The nature of the cementing agent is very important. According to the description the possibility appears to be in no sense excluded that I is a layer oE, similar to the lixivium, (described on pages 143-44), lying upon I_3 (ore deposit) and I_2 (white clay or loam), from which the iron has been leached. In that case there would exist an analogy with the old profiles of the region to the north of Roeteng in Flores (see page 236). In Frontispiece A one would find these conditions in stage 4. Since the altitude is about 1,200 m. above sea level, the surface soil of the red earth can be much more humous than in Flores. Closer research both upon the samples as well as at the site itself, particularly down deeper, is certainly very desirable.

Then it is also a question whether the following Profile No. 7, from Adjanbaki, north of Kapan and lying south of sample sites Nos. 9 and 10, is closely connected with it or not:

I = 0-15 or 20 cm. Dry surface soil, red, laterized.

II = 15 or 20-40 cm. Moist, sticky, dark red.

III = 40-? Padas, reddish yellow (and what lies under it?--E. C. J. Mohr).

This place lies at 1,170 m. above sea level. Judging by the coffee which was growing on it, it is a good agricultural soil.

In addition there are found in the

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above-mentioned report of agricultural adviser Straub all sorts of remarks which relate only indirectly to the soil itself, but rather relate to the use which is made of the soil; therefore they are discussed in the following section.

Summarizing what has been discussed above, we come to the general conclusion that in Timor on the hills and on the higher mountain lands the soil, although frequently shallow cannot be heavy and impervious, due to a climate which almost never produces a lime-free heavy clay.

There are not many plains, but those that exist have heavy soils. Some examples are the plain back of the bay of Koepang, on the southern coast, around the mouths of the Noil Mina, and farther northeast, along the Noil Benain. If, in the east monsoon calcareous earth from the southeast blows out over it regularly, then this process promotes a physical and chemical improvement of the soil. The large rivers bring another sort of silt than is carried by the S. Rokan on Sumatra, or the Barito on Borneo. Therefore the plains of the Waiwikoe and the Waihali give evidence of great fertility. Practically nothing is known about those plains along the Noil Mina and the tract is still nearly uninhabited.

Along the central course of the Noil Benain which runs in a southwestern-northeastern direction there lies likewise a plain which is practically uninhabited. The supposition is obvious that the lack of occupants is because of the fierce drought in the east monsoon. If the alluvium is sandy, then the soil is presumably reddish gray. If it is heavy and predominantly clayey, then it must be black to dark gray.

Evaluation and Utilization of the Soils

Many who have travelled in Timor and put into writing their impressions refer to "the alarming deforestation of Timor, as a result of which the already thin layer of earth is eroded away and the stony subsoil comes to the surface." It is, however, a question whether, even in earlier times with a sparser population, the greatest part of the island was ever forested. When Gramberg[98] in 1870 travelled through West Timor, he recorded that there was forest at various places, but concerning the environs of Bakoein (on later maps: Bokwien) he wrote as follows: "Involuntarily one is reminded of an English park when one sees the scattered groups of trees and weakly rounded slopes, covered with a soft grass sod, where the horses can cheerfully graze." The locality referred to is on the slope of the mountainous land toward the northwestern coast. There is a fierce east monsoon and the park landscape is the natural result of this (see Figs. 104 and 105, page 270). The vegetation has probably never been anything different in the entire coastal region from the north of Koepang bay to Atapoepoe, and still farther to within the Portuguese Territory (see also Fig. 106, page 271).

Also behind Koepang, in the depression of Amanoeban to south of Beboki, and on still other terrain seldom may any other vegetation ever be expected than savanna (see Fig. 107, page 271), with here and there a few trees or groups of trees. Reforestation alone would not have much effect. Although the soil does not appear to be bad, it is probably quite thin (see Fig. 108, page 272).

There are certain parts of Timor where favorable climatic conditions prevail and where substantial forests must have stood. These have been unjustifiably chopped down, and only with difficulty and with much expense can the land now be reforested. But in order to provide a more balanced run off and higher minimum flow for irrigation, reforestation must be practiced. The amount of rain that falls upon the island is certainly not so small that one would have reason to despair.

Gramberg called "the Babauw district a dreary, infertile plain, with a scant supply of water." But farther on he recorded that Babauw is the rice barn of Koepang, since rice paddies are laid out there in the rainy season. The land is quite good, the question being entirely one of water. And this is the case not alone near Babauw but at a number of other

98. J. S. G. Gramberg, Verh. Batav. Gen., 36 (1872), p. 162-217.

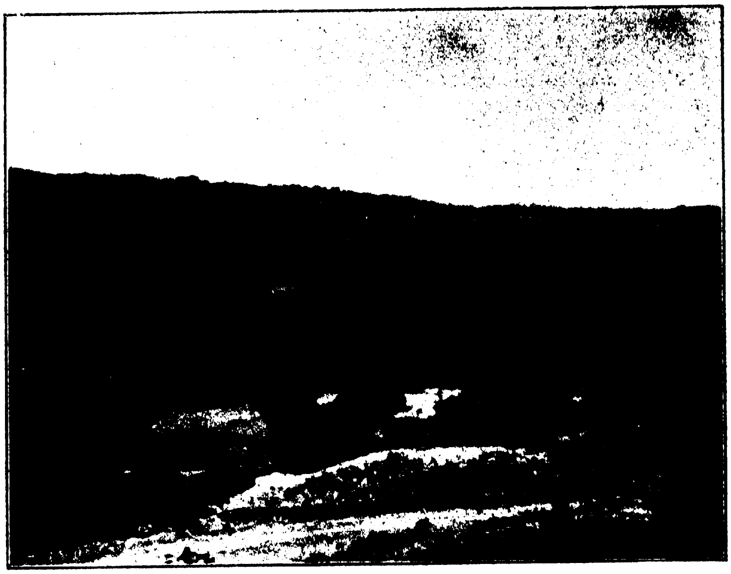

Photo by H. T. Bijlmer

Fig. 104. Southwestern Timor.--Country near Soë. Almost a tree savanna on poor, thin soil on calcareous marl.

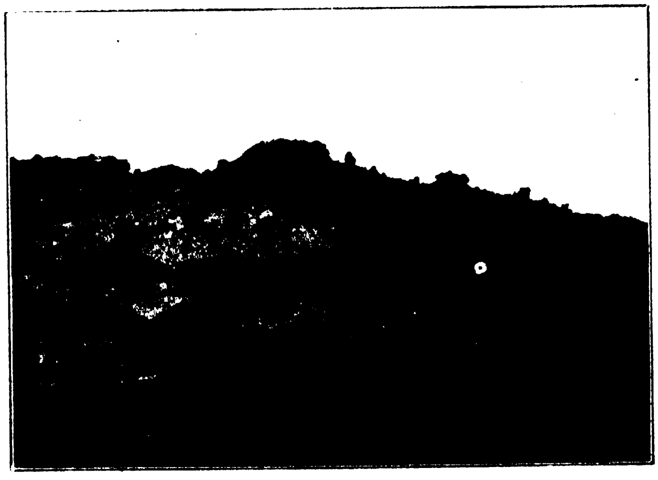

Photo by H. T. Bijlmer

Fig. 105. Central Timor.--Typical landscape. Tree savanna with umbrella shaped Acacias.

Photo by H. Witkamp

Fig. 106. The plain of Caibada (Saibada?) Portuguese Timor. No longer savanna, but steppe, closely approaching desert.

Photo by H. T. Bijlmer

Fig. 107. Southwestern Timor. Savanna near Soë. Low, gnarled forest in and along a stream cut.

Photo by D. F. Bunte

Fig. 108. Southern Timor.--Leafless trees in the fierce dry season on shallow, stony soil.

places on Timor. One would be astonished as to how many rivers and creeks have water the whole year through, although there are also many which in the dry time are completely dry, once the heavy floods of the rainy season are over. Kruijt[99] records rice paddies near Noil Noni, which can be laid out only in the dry season, since the river from which water must be obtained flows the year around. But in the wet season it frequently floods so strongly that irrigation ditches cannot be constructed. When circumstances permit it, a number of smaller irrigation works on Timor will most certainly give important results.

As Molengraaff[100] has repeatedly remarked, it is true that Timor especially in and along the depression is geomorphologically a young land, since it first arose above the sea later than the Pliocen and is still rising. Hence the river valleys are steep and deeply incised. Beside the difficulties which this topography presents in laying out highways, it is a serious hindrance for irrigation works. It can also easily be understood why the primitive inhabitants, with the only meager means at hand, could accomplish but little. Be that as it may, it seems to me that there are undoubtedly still great opportunities on Timor for Occidental technic.

We may safely base this statement upon the following considerations: Scanty, poor quartz sandstone lands are scarcely to be expected on Timor, since the rocks which produce them are very much in the minority. Just as little to be expected

99. Alb. C. Kruyt, l. c., p. 789.

100. G. A. F. Molengraaff, Versl. Ind. Gen. (1911-'12), p. 205 (Vergad., 26 Mrt. '12). The same: Versl. Kon. Akad. v. Wet., Amst. (29 Juni 1912).

are heavy, but radically leached out soils, (NN) since the climate gives no occasion for this. If the rocks, in general, were not rich in lime, and in the dry season the soil was not subject to severe wind erosion, intermittent washing out (Nr.) might lead to this. This erosion lessens the thickness of the layer of mould, but on the other hand it incurs a continual rejuvenation. Continually new rocks are exposed to weathering. Where, however, the soil lies flat and continuously wet, as in places back of the bay of Koepang, near Pariti, very heavy clay does exist. From the nature of the case, as long as marine clay is submerged during high water, nothing can be cultivated on it. However if it comes to lie above even high water, more is to be expected of it.

If in conclusion it is realized that chemically, as to the P, Ca-, Mg-, and K- content, most Timor rocks and especially the extensively occurring Permian formations are far from poor, then in this respect also, the prognosis is favorable.

The facts in no sense contradict this. Gramberg[101] described the beautiful valley of Lelogama as reminding one of the Preangar. "In the longest part of this valley flowed a clear brook. All houses had gardens;--everything pointed to the fact that here was a large prosperous village."

Van Rietschoten[102] who in 1912 travelled over Timor mentioned, besides Lelogama, also Nefokoko as a prosperous tract. To the west of Kapan he found much coffee growing. Different writers and officers of the Home Department also record good stands of coffee and point out the possibilities of extension of this culture in the mountainous regions.

The attention of Van Rietschoten, however, was drawn especially to the plains. He considered the plains of Nai Timoe and Aoeroeki in northeast Netherlands Timor relatively fertile. Mandeo plains impressed him as being less fertile but then he says that this impression was incorrect, for here and there they obtained even 3 harvest per year.[103]

Molengraaff[104] pointed out that "superb soils, originating from the weathering of loose young products of eruption, (efflata soils) are not found on Timor..... Nevertheless the land is very favorable for maize and grass. I have never seen an island, except Soemba, where the grass is so excellent."

That the large Waihale--Waiwikoe plain is fertile, is evident in the first place from the occurrence of very many coco palms. And in addition to the food crops rice and maize, areca (betel) nut palms (Areca catechu L.), aren palms (Arenga pinnata (Wurmb.) Merr.), gebang palms (Corypha gebanga), and pamyra palms (Borassus flabellifer), kinds of pandans (Pandanus spp.), kapok, fruit trees, and even tobacco are growing well. The growing of sweet potatoes (Ipomoea batatas (L.) Poir.) indicates a lighter alluvial soil while plantings of peanuts and cotton mark the heavier alluvial soils. Although occasional dry years with crop failure occur, in general, the soil receives adequate water and a prosperous agriculture exists.

In the south of Amanoeban and on the other side of the Noil Mina, to the south of Amarassi, there seems to be another large plain, but up to now it is uninhabited. It is stated that in this locality is found the densest forest of Timor, a true tropical high forest. It will be interesting in the course of time to learn whether peat formation also occurs there. According to the conditions which limit peat development as given on pages 108 and 157, the richness in lime of the surrounding mountains and of the river valley of the Noil Mina greatly reduces the possibility of peat formation. In descriptions of the Waihale-Waiwikoe plain no mention of peat has been found.

Although today but little dense foest occurs upon Timor, there is still found a good deal of thin forest (see Figs. 103, 104, and 105). It is mostly a sort of low forest: along the coast mangrove (especially Bruguiera); in moist places with fresh water, duri bamboo (Bambusa bambos), but also tamarind (Tamarindus

101. L. c., p. 187.
102. Meded. Encycl. Bur. Batavia--Afl. 3 (1914) p. 9?.
103. L. c., p. 75.
104. In: Voordr. Ind. Gen. (26 Mrt. 1912). See: Versl. Ind. Gen. (1911-'12), p. 20c.

indica); and in addition gebang palms (Corypha gebanga). Here and there, there is quite a good deal of kosambi (Schleichera oleosa) or pilang (Acacia leucophloea); and somewhat higher are Casuarinas. Lower down in dry regions are countless palmyra palms (Borassus flabellifer), and higher up is much cajiput (Melaleuca leucodendra). In the report cited, Straub postulates that where Eucalyptus and pilang make way for stands of Casuarina and tamarinds, the soil ought to be better. Perhaps this is mostly a question of available soil moisture, but as yet this subject has not been studied.

Areca palms (Areca catechu) and cocos have been planted only on the better (usually alluvial) lands with adequate moisture. This is also true of fruit trees. The success of such Leguminosae as dadap (Erythrina) and ipipil (Leucaena glauca) as well as the natural rise of Acacia leucophloea and tamarind, points to a natural richness, at least to an adequacy of mineral nutrients. Nitrogen (and humus) presumably are in the minimum. This corresponds with the heavy erosion in Timor which, if not restrained, either washes off or blows off all humous surface soil.

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In conclusion, let us pause just a moment to look at a picture of Central Portuguese Timor, reproduced as Fig. 106. Such a desert-like landscape is certainly an extreme of what the Indian Archipelago exhibits.

* * * * *

NETHERLANDS NEW GUINEA

Only in recent years has a general interest been taken in this region. To a great extent this interest arises from the supposed possibilities of an agricultural nature, possibilities which are most connected with the nature of the soil. Since I was not able to see this land and learn about it at first hand, I am obliged to borrow all data from the communications of others. But it is advisable for us to give considerable attention to the soil of Netherlands New Guinea.

But this is a difficult task because of the scarcity of direct observations relating to the soil, to say nothing of the absence of systematic descriptions of soils in the literature. It is of course not the case, but it would seem as if researchers in the natural sciences, such as geologists and biologists, and also officers, civil servants of the Home Department, missionaries, physicians, etc., have always been careful to avoid recording any information regarding the soils of the regions in the descriptions which they gave of districts travelled through for the first time! Presumably the reasons for this are, however, negative rather than positive. That is, they gave only general attention to the soil. Therefore even today I am still almost entirely limited to indirect deductions from observations of an entirely different nature. It is sincerely hoped that the reader will keep this in mind, particularly with reference to the soils of New Guinea.

Before commencing a consideration of the subject under the usual headings, let us consider a subdivision of this vast region. Usually the "Birds's Head" (Vogelkop), the western part up to Geelvink Bay, is considered separately. Also in conformity with the example of Zwierzycki[105] the enormous region easterly from that may be divided into 5 strips, running more or less east and west:

1. Northern coastal plain
2. The Northern Watershed mountain range
3. The central lake plain (Meervlakten)
4. The Snow Mountain range
5. The Southern Coastal Plain

The "Bird's Head" will be discussed lastly, under (6).

105. J. Zwierzycki, Toel. b/d blad. XIV en XXI der Geol. Overz. Kaart v/d Ned. Ind. Arch., Jb. Mijnw. (1927), Verh. I, pp. 248-308. There also a bibliography of geological literature.

Soil-Forming Rocks

Nos. (1), (3), and (5) of the above-mentioned subdivisions of East Netherlands New Guinea are of alluvial, and locally of course also of colluvial nature. Consequently the soil forming rocks will have to be sought elsewhere, i.e. in regions Nos. (2) and (4), the mountain ranges. While the northern watershed mountain range and the Snow mountain range may, in many respects, differ considerably geographically and geologically, yet petrographically, at least from the standpoint of this book, the similarities are much more striking.

In both mountainous regions igneous and sedimentary rocks as well as metamorphic rocks are found. The centers of the folds and ridges are granite and diorite as well as crystalline schists. These are flanked on the north and south and covered even to high over the top by older and younger sedimentary rocks, from Devonian, through Permocarboniferous, Jura, Palaeogene and Neogene to Quaternary. Besides granite and diorite in the central ranges, there are also basic igneous rocks such as diabase, gabbro, and serpentine. Younger eruptives, such as andesite and basalt have been found only very sporadically in this part of New Guinea.[106] Those that do occur are of Old Neogene age. It is because of the relatively unimportant volcanic activity of that period that only in the lowest Neogene do tuff sandstones and conglomerates of lime with andesite or basalt fragments occur.

Nearly all the sedimentary rocks are marine, since in all formations except the Devonian and the youngest Neogene (the brown coal zone), marls and limestones are particularly dominant. The Neogene seems to occupy the greatest surface and is very rich in marls, marl sandstones and limestone. The Snow Mountain Range appears to possess still much more Neogene limestone than does the Northern watershed mountain range (see Fig. 113, page 280). The calcium carbonate is in part coral lime, and in part Foraminifera lime.

Sandstones, sometimes with muscovite, sometimes containing iron, are found in the Devonian, and in the Paleogene and Neogene. In the Jura formation, many black silicious slates occur. In the Paleogene are characteristic purple and green marl shales and slates. Besides lignite, soft sandstones, and clays in the younger Neogene, only rocks of this period are said to include typical brackish water and fresh water sediments of the period of the beginnings of transformation to land.

In brief--all kinds of sedimentary rocks are to be found upon New Guinea. The areal extension of the different types, however, is as yet undetermined.

The rivers flowing from the Northern watershed mountain range and the Snow Mountain range undoubtedly must have been carrying much silt and sand toward the low land for a long time. It is from this material that the Northern coastal plain, the central lake plain and the southern coastal plain have been built up. The character of these plains is discussed in a subsequent section.

The "Bird's Head," West New Guinea, is tectonically somewhat differently built up than East Netherlands New Guinea.[107] It is apparent that the western continuation of the Snow Mountain range, to the south of the Geelvink bay, bends around toward the north northwest. The Northern Watershed mountain range continues westward over Japen island, so that both chain complexes unite in the "after head" of the Bird's Head. There do not appear to be essential petrographic alterations of the central chains. Yet, both in the east and in the north of west New Guinea, crystalline schists, granite, diabase, gabbro and serpentine are found. Above them is some Permocarboniferous, much Jura and perhaps some Chalk.

The interesting difference is, however, that where the north and south chains come together very likely a quite extensive young volcanic mountain range makes its appearance, the Arfak mountains (see Fig. 109, page 276), consisting of andesite and basalt. West northwest along the whole northern coast from the Prafi river in the east to as far as Sorong in the west and

106. Zwierzycki, l. c., p. 288.

107. J. Zwierzycki, Toel. b. blad XIII der Geol. overz. Kaart v/d Ned. Ind. Arch., Jb. Mijhw. (1930), Verh. III, p. 1-55. With bibliography of the geological literature.

Photo by Goozzen

Fig. 109. West New Guinea. One of the Angi lakes, in the Arfak mountain range. In the foreground poor, natural vegetation.

even a little on the island Salawati, there is a still more extensive andesite region which, here and there alternates with Neogene.

South from the old mountain chains mentioned, also upon Bomberai peninsula, the lower jaw of the "Bird's Head," is the principal Neogene with very much limestone. Along the open beak, the MacClure gulf, very low alluvial plains lie spread out to the north and south. The southwest side of the small part (the lower edge of the neck) has a large Paleogenic limestone mountain range.

Also upon the extreme northeastern part of the Bird's head is Neogene with limestone on the surface. The important town of Manokwari is built on this formation.

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If the above be condensed into a few words, then it may be said that the soil-forming rocks of Netherlands New Guinea in the main are entirely different than, for example, those of Java and Sumatra. They are more like those of Borneo. There is a great diversity of sedimentary rocks, for the greater part more or less calcareous. Next in importance are old igneous rocks and crystalline schists. Volcanic activity in Netherlands New Guinea is limited to two small regions in the north of the Bird's Head. There are a few other sporadic occurrences, more as an interesting accessory, in the Neogene of the northern coastal mountains of Eastern Netherlands New Guinea.

Climate

What is known about the climate of Netherlands New Guinea is relatively very little. This knowledge rests upon regular observations, taken at a few places along the coast, and further upon numerous incidental measurements and observations made during the different expeditions and reconnaissances in the interior. Braak[108] in 1929 collected the available material in a

108. C. Braak, Klimaat v. Ned. Indië, Dl. II, p. 502-529.

very creditable manner. Three years later the "Board for Studying New Guinea" issued a report[109] under the title "The Indian Committee for Scientific Researches," in which there is found a short but good comprehensive digest of Braak's data, supplemented with more recent data which Braak did not have.

For the purpose of this book we must view the literature from a somewhat different angle than those writers did. The first cardinal question is not as to whether the climate is physiologically agreeable for man who may go there to settle, but rather--what is the soil climate there? What type of weathering occurs? This leads us to the following discussion, which as far as practicable rests upon factual data, but which must include all sorts of hypothetical elements.

The Temperature.--Because of the great height to which the Snow Mountain Range rises, not alone in a few, isolated summits, but in long ridges and even considerable highlands, no other single island of the Netherlands East Indies Archipelago shows such great temperature differences as does New Guinea. But since the effects of the monsoons are relatively slight, any one point on this extensive land exhibits little variation in temperature. Only the south coast, facing toward Australia, is influenced by that large continent. The average temperature, during the season of the wet monsoon is as high as elsewhere in the Indian coastal regions, namely a little above 27.5°C. But because of the Australia winter in the dry monsoon, the temperature falls to 24.3°C, thus a little more than 3°C lower. In the west and especially along the north coast, the temperature is much less variable. At Manokwari, for example, the average monthly temperature maximum is 26.5° C (Nov.) and the minimum is 25.7°C (Feb.). Thus the difference is not even one degree C.

Since New Guinea is still for the greater part covered with forest, the soil temperature will not differ much from the average air temperature, and quite closely conform to the formula: t = about 26° - 3/5 n, in which n is the elevation in hundreds of meters. But where the forest is lacking and cogon is the principal cover, such as in the wide zone of savanna to the north and northwest of Merauke, (Fig. 110, page 278), or on the north coast here and there about Humboldt bay (Fig. 111, page 278), the temperature most probably runs up a couple of degrees, especially in the upper surface soil. And where there is bare, clean cultivated soil, in the above formula in place of 26° as much as 29° may have to be written.[110]

At approximately 1,500 m. elevation the soil temperature must consequently be approximately 17° to 18°C. At 3,000 m. elevation it is approximately 8 to 9°C, while at about 4,400 m. the snow line is reached. This is only 2,000 m. higher than in the Alps. (See Figs. 112, page 279, and 113, page 280.)

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It is generally known that while the average annual temperature of the Netherlands agrees fairly well with that of approximately 3,000 m. elevation in the tropics, yet the climate of the Netherlands and that of a tropical mountain country of New Guinea at 3,000 m. elevation (see Fig. 112), is far from being equal for man and beast. Also it is known that quite another flora occurs. But the relationships with respect to the soil are less generally realized, and yet these are important. For on New Guinea's highland the soil temperature the whole year through is 8 to 9°C, and is never higher than approximately 10°C and never lower than approximately 7°C. For soil bacteria the conditions are therefore never favorable. For molds, however, which are quite at home at the relatively low temperature, it is always favorable 12 months in the year. Conditions are also favorable for mosses at the summit. If the moisture condition in the soil is also the same throughout the year, then here there is indeed a typical "eternal sameness." In the Netherlands, on the contrary, the soil temperature of the surface soil in the winter

109. Rapport van 21 Mrt. 1932, afz. gedr., p. 5-9.
110. Compare this book, pages 42-45.

Photo by Versteegh

Fig. 110. Southern New Guinea. Savanna behind Merauke, with Pandanus. Blackearth?

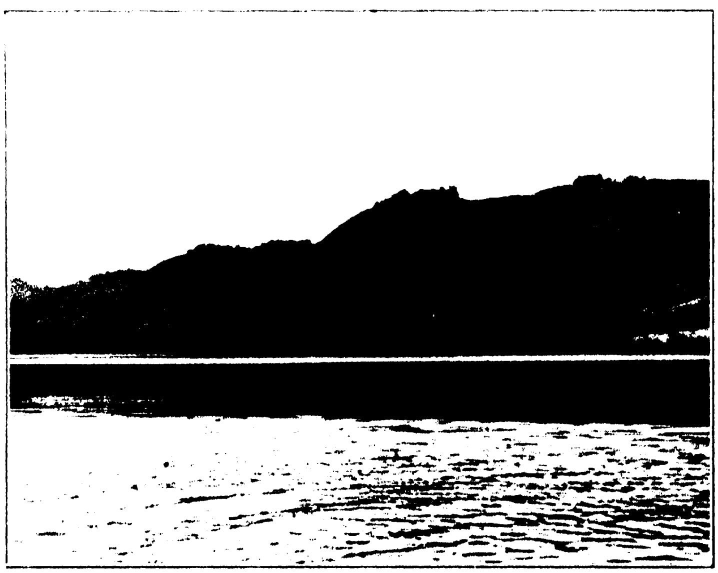

Fig. 111. New Guinea. Hills along Sentani lake. Deforested by kaiñgin cultivation. The poor soil shows but weak and slow reforestation capacity.

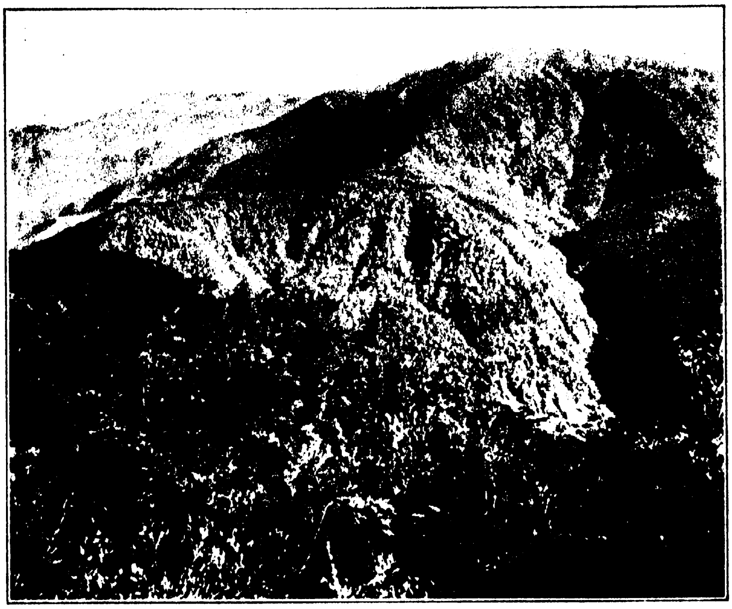

Photo by A. Pulle

Fig. 112. New Guinea. Wichmann peak (3,125 m.) and in the distance at the left Wilhelmina Mountain Range (above 4,000 m.) seen from the crest of the Treub Mountains (2,365 m.).--At the elevation of 2,000 to 3,000 m. everywhere still closed high forest, under which is humous surface soil.

falls close to and below the freezing point, while in the summer it may go to 16 to 18°C, yes, even to above 20°C. After a quite complete inactivity in the life of the flora and fauna during the winter, a period during which an intensive bacterial life can develop follows in the summer. Mold vegetation becomes dominant in the autumn and somewhat less so in the spring. It is obvious that the content of nitrogen compounds, in particular of nitrates, in the course of the year in the Netherlands must exhibit variations which are precluded in the tropical highland. Stating the above in general terms: the conditions of food supply of the vegetation in the two above-mentioned tracts of the earth are bound to be very different. The vegetation itself and the residues which remain behind on and in the soil, the so-called humus, and likewise the ultimately accumulated peat must also be different.

In the tropical highland where the soil is not heavily shaded by forest--the uppermost layer of the soil, of perhaps 2-3 cm. depth can attain a sufficiently high temperature, so that considerable nitrification can occur. This may be the case under thin forest (see Fig. 114, page 280) where the root systems of the trees are found just below the surface of the soil. In the Netherlands, on the contrary, during the summer the warmth penetrates deeper, and the hardwood forest is thicker and can extend its network of roots deeper. As a consequence, surface erosion removes from the tropical highlands surface soil of relative higher value than in Central Europe. Erosion is thus more detrimental, and the silt coming from such highlands is of relatively more value than river silt in Central Europe.

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With respect to rainfall, a part of Netherlands New Guinea can be at once

Telephoto by P. F. Hubrecht

Fig. 113. New Guinea.--View of the high mountains with Wilhelmina Peak (4,700 m.)--includes more than 1,200 m. difference in elevation, and thus above perpetual snow without vegetation, on a soil of rock fragments almost or entirely unweathered. Foreground: still closed forest, which higher up changes over into elfin wood and bushes.

Photo by G. M. Versteeg

Fig. 114. Southern New Guinea. Small Papuan camp on the upper Sando River.--Light high forest, with many vertical trunks and poor undergrowth.

differentiated from the rest, namely the southeastern part of the southern coastal plain. This portion has a very distinct dry monsoon. In the rest of that extensive region in some years a few dry months occur, but for the stations for which the Observatory at Batavia has published rainfall figures (see Table 69) there is not a single station which shows even a single month with an average less than 70 mm.

also indicate nothing about this. The conclusion is that with the exception of the southeast, the natural vegetation for the whole of Netherlands New Guinea is an unbroken tropical high forest. This is not far from the truth.

In the report of the "Board for Studying New Guinea" (1932) a few remarks were made[111] which might be included here: The further west along the southern coast

Table 69

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON NETHERLANDS NEW GUINEA[1]

	Height above sea level (meters)	No. of years of observations	Number of rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Rainfall	Number of wet (humid) months	Number of dry (arid) months
Hollandia[2]...	about 3	13	131	300	306	295	209	157	145	152	161	103	146	164	202	2339	12	0
Domta........	sea level	13	137	462	303	412	335	259	203	166	189	168	158	298	414	3366	12	0
Sarmi........	about 2	10	147	304	205	248	195	219	206	239	208	214	203	225	227	2694	12	0
Jendeh.......	about 2	15	197	383	397	395	313	377	289	245	294	330	343	311	339	4016	12	0
Windosi......	80	24	200	318	296	338	301	304	322	218	244	262	261	253	244	3361	12	0
Manokwari....	30	29	140	301	247	331	272	201	191	140	140	120	111	163	271	2489	12	0
Sorong.......	sea level	25	184	171	173	195	240	291	338	339	233	255	175	169	177	2755	12	0
Babo.........	about 4	16	145	251	280	282	236	247	161	106	89	146	183	194	216	2391	11	0
Kokas........	32	15	147	435	356	347	284	164	167	138	70	94	138	149	297	2639	10	0
Fakfak.......	52	20	171	252	225	226	287	373	327	269	246	262	298	201	212	3178	12	0
Kaimana......	sea level	15	150	160	222	280	350	283	198	135	96	121	167	172	189	2375	11	0
Okaba........	about 3	10	[illegible]	271	228	288	192	137	45	43	11	19	79	110	213	1633	7	4
Merauke......	about 8	20	[illegible]	258	239	255	181	125	45	38	23	30	46	85	202	1562	6	5
Tanah Merah..	40	3	208	318	397	494	500	490	228	230	349	236	489	299	386	4417	12	0

1. In the already repeatedly cited Verhand. No. 24. (up to and including 1928), besides supplementing of the data with that for 1929 and 1930.
2. Hollandia, Domta and Sarmi lie along the eastern part of the northern coast; Jende, Windosi and Manokwari along the west coast of Geelvinck Bay; Sorong close to the west cape; Babo and Kokas on McCluer Bay; Fakfak on the west coast of Bomberai; Kaimana further southeast on the coast; Okaba and Merauke entirely in the southeast; and Tanah Merah on the Digoel River.

This however, does not mean that there are not places which do have continuous or average dry months (under 60 mm.), but as yet there are no figures available for them. As to the rainfall of the entire interior nothing is yet known. The occurrence of continuously or periodically dry regions is, however, not probable. The exceptions would be plains surrounded on all sides by high mountains, as the high plain of Bandoeng. But it is not likely that they will be severely dry. The data collected at the time of the different expeditions

from Merauke one goes, the less noticeable the influence of the dry southeast monsoon becomes. Even from the Digoel river "no difference is to be observed in rainfall between the west and the east monsoons. It is stated that of the 365 days of the year, it rains approximately 300 days." Where and how long that has been observed, is not recorded. However among all the places in New Guinea for which the Observatory gives figures, there is not one which, over a sufficiently long time, shows averages above 200 rainy days. And except the

111. L. c., pp. 6-8.

Pangeranggo summit with 284 rainy days there is not a single station in the entire Netherlands Indies that exceeds the figure of 250 rainy days per year. Southwestern New Guinea is, therefore, a region where additional rainfall figures are certainly desirable. Whatever the figures may show, there is no doubt about the absence of a dry season. On the contrary--the further west one goes, and the closer to the mountains one comes, the rainier the climate. This is understandable and has been proven by observations. It always rains heavily on these mountain slopes.

In the above-mentioned report it is inferred that along the northern coast the climate becomes drier because of the increasing occurrence of grassy plains toward the east (see Fig. 111). It is, however, very much of a question whether these are natural grass plains rather than artificial ones, for the rainfall of Hollandia, the most easterly located station, shows (if one includes the years 1929 and 1930) no single month with an average less than 100 mm. Therefore, forest would naturally be expected. Fire in connection with kaiñgin agriculture has rightly been pointed out as the reason for these grass lands. If, however, grass plains occur to the north of Merauke, they can be ascribed to the climate, (which has 5 months drought, during which the rainfall averages under 40 mm. per month). Under these conditions, savanna is the natural vegetative cover.

Ways in Which Weathering Occurs and Resulting Soil Types

Since a dry season is lacking over most of New Guinea, we may reasonably suppose that regions with regular, periodical ascending water movement in the soil are also lacking. There will certainly be localities where in some years long continued drought prevails, but these will be more than offset by the other years with an excess of rain, so that ultimately the leaching exceeds the concentration. The symbols **NN** and **nn** will thus represent the conditions. **NS** or **ns** must be considered as excluded. Perhaps **nvv** occurs in the savanna region of the southeastern corner on the heavy alluvial plain, which lies between the coast and the lower marsh region lying farther inland.

Differential weathering must thus occur principally according to the temperature; that is, according to the elevation. Aeration is also an important factor. Amphibian weathering (**am**) would occur on those areas that stand entirely under water in the rainy season, but which in the east monsoon become dry enough that during the hours or days that it does not rain, air can penetrate into the ground, although the ground is relatively wet or only moist. The **am** type of weathering occurs along the rivers and lakes which, during the months of the greatest rainfall, show a water level a few meters higher than in the months of lesser rainfall.

* * * * *

Coming now to the soil types we will consider them under the same geographical subdivisions under which we discussed the rocks.

A. The Eastern Part of Netherlands New Guinea.--

(2) The Northern Watershed Mountain Range.--According to surface area the Neogene mountainous land is the most important. From the limestones and marls which occur in these formations soil types have originated which, for the greater part, have been determined by the admixtures in the limestone and marl. The impurities and their weathering products remain after the more soluble $CaCO_3$ has been dissolved out. The altitude varies from less than 100 m. to somewhat more than 1,000 m. Therefore the region is within the climatic groups **He** and **Wa**. The permeability depends upon the nature of the admixtures, but unfortunately little is known about them. It is only known that here and there andesite and basalt gravel is found under the soil. In these localities, brown to reddish brown, more or less crumbling calcareous red earth, lixivia of the formula **(K + V.b)--(He to Wa).NN.ae (2-4)** lie on the calcareous materials. If the marls possess strongly weathered loam and clay which were deposited as alluvium, then the soil formula will approach **(K + Kl)--(He to Wa).nn.ae** to **am)**.

(2-4). This would cause a red-flecked clay soil on low knolls. Such a soil has a tendency to slide on the slopes and cannot develop to great thickness. From experience in northeastern Banjoemas and Kedoe (Java) this type is known to be very unstable. This is especially true, when the forest no longer covers the soil. If the marls contain much quartz sand, then the stability is increased, but the fertility is not.

In his description of this Tertiary hilly terrain[112] Zwierzycki speaks of "weakly convex hills with slowly flowing rivers between them." Whether or not these rivers carry much silt is not recorded. There are "few rapids and almost no waterfalls in the rivers and moreover landslides on hilly slopes are absent." From this it may be concluded that true marls (lime + clay) seldom occur here; otherwise there would be more landslides. In consequence the soil must have originated from fine sandy limestone and exhibit pale red tints. "Everywhere erosion is far advanced," says Zwierzycki, and he adds: "mature relief forms are developed." This explains the weakly rolling hilly land. But, if the conclusion is accurate that the soil consists of pale-red sandy loam, it can hardly be very fertile. The following quotation is a confirmation of this:

"The hills on the shores of the Sentani lake and on the Jotefa lagune are deforested and covered with cogon (Imperata spp.) (see Fig. 111). Elsewhere the entire hilly tract is covered by unbroken tropical high forest." (This last is as we should expect with the prevailing climate; note what was said on page 281.) "The tropical high forest of New Guinea, which frequently is called impenetrable in comparison with that of Sumatra and Borneo, impresses one because of the scarcity of undergrowth between the big trees. Rattan is almost absent and lianes are also not numerous. The wild Papuan tribes can easily go about in the high forest without using a bolo (to cut their way)."

The forest officers have established the fact that the more fertile the soil, the heavier the development of undergrowth in the tropical high forest. Therefore, a forest of a few tall trunks without lower vegetation is always considered an indication of unpromising soil.--It may be safely concluded from the words of Zwierzycki that the soils of these Tertiary hills and mountains are far from rich because they are mature and apparently have been diluted by great quantities of quartz, as fine or medium sand. The humus content is unimportant at low elevations and even at greater elevations, it is not high.

On the schists of the Cyclops mountain range a soil of good physical characteristics has apparently developed. The parent rock is, on the average, rather rich in amphiboles, chlorite and biotite. Epidote, albite, and quartz, and sometimes calcite, play a part in the formation. Apatite is seldom mentioned in the descriptions[113]; thus much phosphorus is not to be expected in the soil. Where the land has been deforested, probably much surface soil has been washed off by sheet erosion.

What the soil types will be on all the different rocks in the Cyclops mountain range, and in the Gautier, the Foja, the Darifoera, the Karimoor, and the Bawani mountain ranges, cannot be described without local investigation. In the absence of this field work, only vague generalities can be stated. It is certain that the Neogene mountainous land is covered with overmature soil. If the soil as a whole is thick and deep, then in this warm humid climate it must also be senile, especially in the uppermost layer or layers. But the soil on steep slopes is less senile, because only a short time has elapsed since it originated from weathering rocks. It is, of course, very shallow, lying still close to the unweathered parent rock.

* * * * *

(4) What has been said here of the Northern Watershed Mountain Range very probably applies to the lower elevations of the Snow Mountain Range. Above 2,000 m.

112. J. Zwierzycki, Versl. Geol. Mijnb. onderz. i/e geol. v. Noord-Nieuw-Guinea, Jb. Mijnw. (1921), Verh. I, p. 100-102.
113. W. F. Gisolf, Mikrosk. onderz. gest. Noord-N. W. Guinea, Jb. Mijnw. (1921), pp. 133-161.

other conditions exist. At least on the acid rocks such as granites and many schists accumulations of organic matter and peat deposits occur, especially on flat places, and gentle slopes. These deposits are different than in Central Europe, since both the frost of winter and the warm summers are lacking here. As to how a "low" peat is built up in a depression at say 3,500 m. and how high peat then develops on it is not known. We can only predict that a leached-out mass of quite acid reaction will be found and under that there will be pale gray and white layers of quartz and kaolin.

* * * * *

In considering the plains (1), (3), and (5) in general it can be said that the allochthonous materials from which they have been built up must be considered as having been mostly, if not entirely weathered.

* * * * *

(1) The northern coastal plain received its main material from the Neogene back country. It is possible that locally on the senile clay and the quartz sand some young juvenile tuff material was mixed in. Therefore, the resulting colluvium or alluvium underwent more or less of a rejuvenation. Apart from that it may however be accepted that the plain consists mostly of heavy loam and clay, hemmed in along the sea by a sandy strand ridge, and cut through here and there by sandy ridges, which are elevated river banks (natural levees). For this reason the strip behind the beach ridge is marshy. It should be considered as a series of lagoons[114] in which, where the conditions are favorable, a little peat forms. If, as a result of the rising of the northern coast, this land should become dry, it will then pass from the **aq** stage into the **am** stage and perhaps even into the **ae**. If, by that time, the ground mass has not been completely bleached, it will change from a bluish gray color toward pale yellow and finally to pale red.

The deeper lagune clay which has been in contact with sea water, has, without doubt, become saturated with various bases. Higher layers deposited from fresh water must be partially unsaturated and hence have an acid reaction. This is especially true where the formation of peat is observed. But where the overflowing rivers deposit calcareous silt, the pH must be higher and peat formation is not to be expected.

* * * * *

(3) The large lake Plain (Meervlakte) located between the two mountain range complexes, lies approximately at 60 m. above sea level. It is accepted geologically that this plain is not rising along with the mountain land and the northern coast; on the other hand, it is sinking.[115] Meanwhile rivers are flowing into this plain, and the level is raised with silt, and along the river edges, with gravel and sand. Of these rivers the Idenburg and the Rouffaer are by far the most important. The outlet of the plain is the Mamberamo river. Whether the plain will be drained quite dry in the near future or whether it will be submerged under water depends upon the degree of sinking of the plain. It also depends upon the rate of silt deposition and upon the extent that the Mamberamo lowers it stream-bed, and hence lowers the water level. This plain now lies half above, and half below water. There are dry parts, but also swamps, and lakes. The greater part of its soil will be under amphibian conditions, while another part remains subject to subaqueous conditions and according to formula would be: **al-He.nn.(am or aq).(l.3).** Intentionally the parent material is designated as **al**. Without closer local studies it cannot be stated which rocks or minerals are the principal ones among them. Moreover there may be large differences between the rocks. Yet, even though we take the

114. Zwierzycki, Jb. Mijnw. (1927), Verh. I, p. 249.
115. Zwierzycki, l. c., pp. 253 and 287.

fragmental character of our knowledge of the surrounding mountains into consideration, it seems improbable that much weatherable material is brought down by the rivers. Most of the silt will probably be senile. Hence **(I-3)**, indicating the stage in the above formula, refers not so much to the weatherable or unweatherable minerals, but to the deposits, which as such are still extremely young. But if, before long, this plain should be artificially drained, cleared, and brought into cultivation, it may be expected that in an astonishingly short time the soil would become senile, since it is doubtful if it possess any mineral reserve which might be the occasion for rejuvenation.

* * * * *

(5) The plain to the south of the Snow Mountain Range shows, as already stated (on page 277), the greatest climatic differences of the whole Netherlands New Guinea. The temperature differences are of less importance than the differences in moisture (rainfall, relative humidity of the air, subaerial or subaqueous position). To clarify our discussion let us divide the plain into three strips roughly parallel to the mountain range:[116]

(a). The low hilly land at the foot of the mountains, well drained, but with much rain, and without a pronounced drought during the east monsoon. The original alluvium and colluvium are weathered to a light or dark brownish red lixivium, which is covered with tropical high forest. Considering the rocks that exist in the Snow Mountain Range and its southern foreland, the soil in this strip cannot be rich and the forest must be relatively thin, although with an abundance of tall trunks of hardwood trees (see Fig. 115, page 286). Europeans have penetrated this zone only along the rivers which cut across it. And since naturally the freshest and most fertile alluvium is to be found along these rivers, the traveller must obviously have obtained a too favorable impression of the soil as a whole. If this deduction appears to some to be inadequately substantiated, we might compare the conditions with those in Palembang, Sumatra, although this in no sense holds good everywhere. Whoever travels in Sumatra up the Ogan and the Lematang rivers to the mountains is struck by the fertility of the swamp lands along those rivers. But he sees nothing of the equally striking poverty of the well drained uplands (talang) lying in between those rivers. It seems to me that the "Board for Studying New Guinea," quite correctly gave only a few lines,[117] to this whole strip of New Guinea.

On a small point of this strip, extending out toward the south, lies Tanah Merah, the settlement on the Upper Digoel. Here the soil is red, and hence well drained. If the soil in the immediate environs of the settlement is still reasonably fertile, then it follows, from what has been said just above, that the farther one goes from the river out onto somewhat higher land, the poorer the soil must become. A traverse from Tanah Merah out toward the northeast as far as the Oewim Merah river would probably show this.

(b) Southerly from the dry strip described under (a), lies the swamp zone. In the west it extends to the sea. Eastwards from the Digoel river to the boundary and farther from the sea, it is separated by a still more southerly lying strip (c), which for the greater part is never flooded.

How the swamp forest is to be considered genetically has not yet been established. It is true, as Zwierzycki says,[118] "South New Guinea is a part of Australia, which has been cut off from it by the submergence of Sahoel Bank and the Torres Strait." But this indicates only one shifting of level. It seems probable that the low ridge referred to (strip c), with reference to the swamp forest (b) has been raised up, and perhaps even now is

116. Compare: O. G. Heldring, De Zuidkust van N. Guinea, Jb. Mijnw. (1909), Wet. Ged., p. 83-203,--and further: the map of Zwierzycki, Jb. Mijnw. (1927), Verh. I, Plaat xv, Blad XXI der Geol. Overz. Kaart v. N. O. I.

117. L. c., p. 11.

118. Zwierzycki, Jb. Mijnw. (1927), Verh. I, p. 287.

Photo by Gooszen

Fig. 115. Southern New Guinea. Papua village on the Bloemen River. River bank shows a profile of pale, slippery loam in the alluvium. The uppermost meter of humous surface soil remains standing vertically. High forest with many, thin vertical trunks, indicating a poor soil.

being raised up, as the beginning of a fold. As to this, however, there are various possibilities to differentiate:

1st--If the whole of South New Guinea, through tectonic movement, had been gradually uplifted then (b) would have risen less than (c). However both would have been raised up out of the sea, and one should find marine sediments in the subsoil. There has not been enough excavation or boring to determine whether or not this is true. But indeed Heldring[119] found gray sandstone or loose sand, without lime, under the so-called red-white clay or loam. This would rather indicate deposits above the level of the sea, hence land sediments.

2nd--If the whole of Southern New Guinea is sinking gradually, then (c) would have to sink less than (b). Then this complex of movements would simply intensify the submergence of the Sahoel plain through the general raising of the sea level. It is possible that at some time the whole marsh strip (b) may vanish under the sea, but the strip (c) as a large flat island would remain sticking out above water, and would later become submerged. In such a case sea sediments can be expected only on top of the submerged terrigenous sediments.

3rd--If it is still possible that the marsh strip (b) is sinking while the ridge (c) is rising with the southern coast, then the future picture will be that the marsh strip will become submerged under the sea, while to the south of this marine strait an island will be rising. Then under the given climatic conditions on such an island there will be a contest between elevation of the surface against lowering through erosion. Such erosion can become very important, since (1) original alluvium, only slightly hardened, makes up the whole formation; (2) no rivers from elsewhere could deposit new material over

119. Heldring, l. c., pp. 89, 99 and 100.

it, and (3) the alteration of a marked rainy monsoon would facilitate wind erosion in the dry season and water erosion in the rainy time. It would then be a question of which would win, the erosion or the elevation of the land, and whether the strip (c) will remain above the sea.

For the time being, however, we have to take into account the conditions of today. Very little is known concerning the soil of the marsh strip. Very probably there has never been a pit excavated in it in order to observe the nature of the subsoil. The supposition can be made that if the strip really should become marshy by the sinking of the land (and this appears to be the most likely), the original amphibian alluvial deposits would become more and more subaqueous. And in so far as the iron would not be leached out and carried away in the increasingly more acid seeping water, the equally dispersed iron would gradually collect in flecks and later in concretions. Consequently peat could begin to form on the surface as was described on page 157 ff. Such peat would intensify the process of acidifying the water and leaching of the bases.

And if such iron-containing peat water comes into contact with sea water, various results may occur. If a river of such water flows into the sea, the pH is suddenly raised from perhaps less than 4, to above 7 and the iron must precipitate out of the water. It seems not at all improbable that a high content of glauconite in marine sediments in front of the mouths of such rivers is connected with this phenomenon. But if the contact with marine salts takes place less suddenly, for example if peat water with an iron content runs over and through marine silt and marine clay, the iron will also precipitate. In this case, however, it will be in the form of definite segregations of iron hydroxide on and in the soil, or as deposits of "ore," which cement the other soil particles together. Moreover it may be as concretions, which possess few inclusions and which have pushed back the surrounding soil particles. In the two publications of Heldring referred to, a number of facts are described which fall entirely within the range of this general conception, and which are correctly ascribed to marine influence.

Before we leave the marsh strip (b), just a glance into the future. If the sinking of the land occurs so slowly that the accumulation of peat can keep up with it, then there is every opportunity for the development of very deep profiles, with many layers of peat, alternating again and again with incidental sand, loam, or clay layers. In the course of a long time the peat changes into lignite, and in a following geological age there will be found a formation, in many respects like the picture which is today brought to light by some borings along the eastern coast of Central Sumatra and Borneo. If, on the other hand, the sinking of the land takes place rapidly, then the sea will push inwards, probably from the west, cover over the marsh, and the peat formation will be submerged. In soundings in the marine strait, which will then be formed, submerged peat will then be found, as was the case a few years ago in the Karimata Strait.[120]

(c) Southerly from the swamp forest (b) lies the low ridge which is nowhere much more than about 20 m. above the level of the sea. Yet this is high enough to permit large pieces of flat or weakly convex land to remain above flood level. Other parts however lie very low and show a very poor marsh vegetation (see Figs. 116 and 117, page 288). The parent materials of the soils which are now weathering, were originally alluvial and thus have been mostly loams and clays. In the course

120. In 1919 when I was studying the sea bottom samples from the soundings of Van Weel a few black specimens were found: these, upon closer investigation, appeared to consist of peat. Besides these there were white, kaolin-rich samples, as well as some red and white flecked ones, similar in appearance and nature to samples of soil from the environs of Soekadana, southwestern Borneo. The samples are in the Pedological Institute at Buitenzorg. Because of my departure in 1920 the results of the research mentioned have never been published. Compare on this subject: Handel. le Nat. W. Congres te Batavia (1919), pp. 219-223 and G. A. F. Molengraaff, De Geologie der Zeeën v. Ned. Indië in: de Zeeën van Ned. Indië, (Leiden, 1921), p. 338-339 (with map).

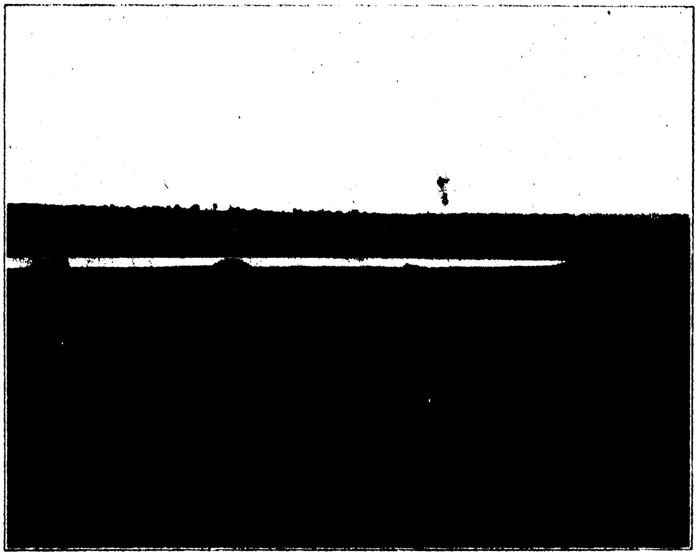


Photo by Gooszen

Fig. 116. Southern New Guinea. Marsh at Inggoer. The Koembe river in the distance.

Photo by Gooszen

Fig. 117. Southern New Guinea. Tree savanna along the upper Koembe river during high water, on blackearth?

Photo by Lorentz Expedition

Fig. 118. Southern New Guinea. Savanna behind Merauke, with Pandanus. Blackearth?

of time these materials have been amphibially and sub-aerially altered into the so-called "redwhite clay" of Heldring.[121] Sandy ridges of a palish yellow color or reddish-tinted by the grains of precipitated iron hydroxide, have been deposited over them. But at present these soils are no longer exposed to flooding, and the climate has a pronounced dry monsoon. Therefore the land has developed a savanna vegetation, and where the soil was sufficiently heavy, favorable conditions for the formation of blackearth have been present. Of course blackearth has not developed on the sandy, pervious portions; these remained a pale reddish color (see Figs. 110, 117, and 118).

There is no mention in the literature of the occurrence of "blackearth" in the savanna strip. The only place, where Heldring mentions black soil is as follows:[122] "The black color which the marine clay, as well as low peat frequently shows even in the dry state, cannot originate alone from plant residues, yet it might sometimes be ascribed to fine carbon particles which originate from fires on the prairies, started by the natives for the purpose of hunting kangaroos, and carried by the wind into moister localities." The validity of this citation could be questioned. In the first place it is doubtful whether what Heldring 25 years ago called black marine clay was really marine clay at all. At present it seems more likely that he had in mind the blackearth as described on pages 164-170, and which because of its toughness and stickiness led him to call it a marine clay. At that time it was not generally appreciated that the blackearth is a soil developed sub-aerially, and it should not be taken amiss that Heldring makes no mention of it. It is difficult, however, to grasp his correct meaning when he[123] states, "Nothing is known about the marine clay deposits in the interior of the land as samples of the soil were not brought along," and immediately follows

121. Heldring, l. c., pp. 89-90, and 99-110. Regarding the inserted explanations there are indeed various things which might be remarked.

122. L. c., p. 130.

123. L. c., p. 128.

this statement: "Between the Marau and the Koembe an extensive marine clay layer of 3 dm. thickness occurs, beginning directly behind the coastal ridge and extending in about 20 km. from the coast. Farther into the interior smaller deposits occur along the two rivers." Without samples for confirmation we cannot tell whether he refers to river alluvium, marine alluvium, or autochthonous blackearth. Likewise we are in the dark when he mentions the sand deposits of Kwarau and Pariar,[124] saying that they should be "black because of their content of clay particles."

In order to try to clear up the uncertainty referred to, I wrote to Father H. Geurtjens. He was so kind as to send the following answers to my questions: "In the back country and sometimes also immediately on the coast there are great expanses of infertile loam, which in the dry season crack open. In the local dialect this soil is called "mamoei" which means "broken up." The natural vegetation is poor grass, with here and there a miserable stunted tree and clumps of pandanus." (See Figs. 116 and 117.)

"The surface soil of these steppes is lead-gray in the dry season and black in the rainy season. Only the lower layers, which are visible in eroded creek and river banks, show very bright colors of yellow, red, brown, and white. The natives like to paint themselves with these materials."

"The caved-off banks along the sea beach have exposed light brown to yellow colors below a thin black surface layer. This land is always characterized by the presence of numerous termite hills which frequently reach a height of 5 m. These are of different colors: some lead gray, others light brown to somewhat reddish brown. Among the wide range in kinds of loam and clay, edible clay speckled with bluish gray is found."

From these statements we come to the conclusion that this is a thick deposit of mixed alluvium, here somewhat sandier, there somewhat richer in clay, but principally loam. It first weathered autochthonously, for the greater part amphibiously but in part also subaqueously (this is the white pipe clay!). During this process, ore (iron oxide) concentrated in and below the amphibian layer, perhaps under the influence of sea water (this dark reddish brown clay, probably deposited upon more bluish gray reduced layers). Then later blackearth originated on the heavier soils under savanna vegetation. However this still requires confirmation by competent observers in the field.

* * * * *

B. The "Bird's Head" (Vogelkop).--

As to the climate, we have stated already that the conditions here are simpler than in the more easterly part of Netherlands New Guinea; a regular dry season is entirely lacking. The rainfall stations, it is true, are not numerous for such a large region but they are well distributed. The rainfall figures all fall under the blue color occurring on the map (Fig. 6). Hence in the soil the water movement is always **NN** or **nn**.

It is true that differences in elevation occur, but in only a few points do the mountains exceed 2,000 m. Therefore **He** and **Wa** conditions predominate and **Ma** and **Ko** are seldom reached.

As already stated on page 276 a large proportion of the surface area is occupied by parent rocks consisting mostly of Neogene lime and marl formations. The rest of the mountain land is of a character similar to that of the Snow Mountain Range. That is a few old igneous rocks, some schists, much older limestone and other sedimentary rocks.

In the back part of the head of the "Bird's Head" lies the Arfak mountain range, with basalt and some andesite. Along almost the entire northern coast there is likewise andesitic mountainous land.

Zwierzycki describes[125] what is known about this, but he does not mention the age. He gives one the impression that in Tertiary time volcanic activity had

124. L. c., p. 136.

125. Zwierzycki, Jb. Mijnw. (1930), Verh. III, p. 35-38.

Photo by New Guinea Expedition 1903

Fig. 119. New Guinea. Moaif river, from Taweton camp.--Water rich in silt; heavy loamy banks. Luxuriant high forest.

started. Even today the reports indicate that Oemsini is an active volcano. This mountain however has not been explored any more than has the more westerly-lying Tamrau mountain range, which also is reported to include an active volcano.

Meanwhile these words: volcanoes, andesite, basalt, etc., indicate especially fertile soil types, as they are found on Java, Sumatra, Bali, etc. However we know that while the parent rock is one of the factors which determines the quality of the soil, there are several others which are equally important.

Nothing has appeared regarding recently occurring intensive volcanic activity. Extensive fields of young, unweathered ash or stones have never been found. If they exist, they are yet to be discovered.

In the report of the "Board for Studying New Guinea"[126] there are various statements about the back country of Amberbaken. On the basis of these I would be inclined to ascribe to the soil the formula: V.b--He.NN.ae (3-4). There are just as few indications of stage 2 as of stage 5. Breccias and tuffs appear to be in the minority. Some of the basaltic lavas of the Arfak mountain range are porous and consequently when exposed by erosion, they weather relatively rapidly.

In short--in these volcanic localities soil types may exist which might be similar to older volcanic soils of Sumatra and Java.

Alluvial kinds of soil are found in great expanses along the whole southern side of the northern part of the Bird's Head. They also occur on the Bomberai peninsula on the northern and southeastern sides. Since all these alluvia are low and marshy and are surrounded on all sides by Neogene rocks, we can easily picture to ourselves how the soils will be--aquatic, (at most weathered amphibiously) bleached, heavy, rich in clay, and something like the pale-gray clay of Figure 119 (above). In a formula the possibilities can be summarized thus:

126. L. c., pp. 22-27.

{(K or M)--He.(MM.ae or nn.am).
(2-4)} al.--He.nn.(aq or am).(1-3).

Without local research this formula cannot be stated more definitely. We are justified in believing that peat must occur on those marshy flats.

Evaluation and Utilization of the Soils

If we based our evaluation of the different soil types of New Guinea upon the use of the soil, this part of our Archipelago would rate rather low, for very little of this extensive land is being used. In "The Government of the Molukkas," that meritorious monograph by A. J. Beversluis and A. H. C. Gieben, it is recorded on page 79 that at the beginning of 1928 in the whole government of the Mollukkas on an area of almost 500,000 sq. km., only 5,000 sq. km. or 1% was used by the inhabitants for agriculture. Only a little more than 1/2% of the last was used for forest exploitation. The European agricultural undertakings occupied but hardly more than 1/10% and the forest concessions (which are not quite the same as forest exploitation) but 0.65%. The balance, (almost 98% of the whole area) is "waste land and forest." If in addition to this we take into consideration that the lands which have been put under cultivation are mostly located in Bangka, Ambcina, Ceram, and Ternate, then the figures for New Guinea become still more unfavorable. Therefore we can safely say that New Guinea is not an agricultural region. Whether it will become something is an open question in which the wish is too often the father of the thought.

In the preceding sections it has been explained that, considering the parent materials, the most fertile soil of the mountainous land of Netherlands New Guinea may be expected in the Arfak Mountain Range and on the andesite along the northern coast of the "Bird's Head." Moreover, the continuous humid climate of these regions does not promote permanent conservation of the fertility. The chances are very good for finding soils which are physically good, but which are thoroughly leached (hence quite senile). In centers of cultivation such soils are more productive, and yield greater profits than in the virgin terrain of New Guinea. This is because it is practicable to incur considerable costs for fertilization, etc. in the more populated regions, where high value products are grown. Thus many hectars of land on the mountain ranges, when the forest is chopped down and burning is omitted, or is carried out very expertly, will, at first, give relatively astonishing harvests of various cultivated crops. But such fertility will last only until the plant nutrient reserves in the forest litter are consumed. When the crops begin to draw upon the reserves in the soil, there is a very great need for replenishing what the everlasting rains have washed out. And then the problem arises as to whether or not the value of the crop will cover the cost. An advantage of the brown and brownish red lixivium soils is that many kinds of crops will grow well upon them. One disadvantage is that according to analogy with other, older volcanic tracts with a similar very humid climate, a very rough terrain with only small bodies of flat land, is usually present. Such conditions require such measures as terracing and ground cover, which need much labor (see Fig. 120, page 293). Nevertheless the above-mentioned regions belong to the most promising portions of Netherlands New Guinea, although the fact that they are still so thinly inhabited should cause one not to raise his expectations too high.

Where autochthonous soil lies on marine limestone and marls the conditions for cultivation are as a rule less favorable. This is the case over a very high percentage of the surface of Netherlands New Guinea. If the limestones contain quartz sand, the soil is quite pervious. The portion of the soil which is not sand becomes brownish red (terra rossa). Chemically, the sand acts merely as a neutral diluent so the soil becomes relatively poorer because of its presence. The resulting lessened water capacity of these soils is a difficulty and a slight drought (for example, a rainless month) is a real danger. If on the contrary, as in the marls, the accessory material of the lime is mainly clay, then the soils are of greater water capacity. They are also chemically richer. But for many crops they are too dense and do not contain enough air.

Photo by A. Pulle

Fig. 120. New Guinea.--Kaiñgin of the Pesechem at Nangoel.--With primitive efforts by means of a few transverse barricades to somewhat retard the heavy erosion.

Moreover such soils are difficult to work and troublesome because they bulge out on slopes. To obviate these difficulties is more difficult than would be expected. On the contrary, it is quite simple to improve sandy terra rossa satisfactorily by means of farm yard manure and commercial fertilizers. This improvement, however, does not last a long time. It may, however, be more than a few decades before things will be so far along that the soil on the limestones and marls of New Guinea will be put into cultivation. When that time arrives it will probably be best to start cultivating where the rocks are tuffaceous, such as in from the northern coast, southeast of Sarmi or east of Sorong.

Crystalline schists, as well as granites and other old eruptive rocks elsewhere in the continuously humid regions of the Archipelago have not proved to be very valuable from the agricultural standpoint. Yet the soil from these rocks should not be estimated as absolutely valueless. Under favorable economic conditions certain crops may prove quite profitable, as has been the experience in Malacca. However, no one knows anything as to what is to be expected of such soils at great elevations, as for example in the Snow Mountain Range at 3,000-4,000 m. Nowhere in the tropics is there a suitable case for comparison, neither in Africa, nor in Central or South America. Where, in those parts of the world, mountainous land of this elevation is found it may be of volcanic nature, as with Kilimandjaro, the Kamarun volcanoes and the Andes. If it

consists of old rocks, as for example the back country of Brazil against the Andes, it is unforested and uncultivated as in New Guinea. As to comparisons with cooler lands of higher latitude a warning in this connection was already issued on page 279. It is not only quite conceivable but even probable that of all Central European fruit trees with the same average annual temperature requirements of about 8 to 10°C not a single one would succeed at 2,500 to 3,000 m. elevation. This is because both the warm summer with days of more than 12 hours sunshine, and the winter with snow and frost and a long continued rest period for the vegetation, are lacking. The tropical crops of the low warm belts are also out of place in the highland. Therefore only the experience of the future can teach which crops are suitable.

* * * * *

The allochthonous soils of the alluvial plains, under suitable management, may prove quite valuable. At present, however, the soils are rather unproductive. This impression is also gathered from the Report of the Board for Studying New Guinea.[127]

Let us begin, for example, with the plain along the northern coast of East Netherlands New Guinea. This strip is considered by geologists to have been uplifted. An earlier coastal sandbank has now come above the sea and forms a long sandy ridge, upon which coconuts grow. What percent of that sand will eventually weather to good arable soil? Presumably not much, for the principal component is unweatherable quartz sand. The area will remain sandy, and the higher it lies above sea level, the greater the chance for lack of water in times of drought and impoverishment in times of much rain. Behind this sandy ridge is "a 3-6 km. broad strip with unwadeable swamps and clear open lagoons." Although if the soil had remained dry a long time, here and there it would perhaps be usable. At present it is inaccessible. With the aid of natural or artificial colmatage, i.e. directing silt-rich flood water into the marsh, or by hydraulic dredging, the region might perhaps be made habitable and suitable for cultivation. The cost, however would be very great. For the time being it seems to be an economic impossibility.

A similar consideration might apply to all those enormous marshes of the Meervlakte, of those along the south coast, and of the coastal plains about McCluer bay. Plans or proposals for reclamation are theoretically conceivable, but fantastic, and economically impossible to carry out.

More can be expected from a couple of smaller tracts such as the Nimboeran plain, which lie around the Sentani lake. This lake lies to the south and southeast of Geelfink bay (see Fig. 121, page 29?). Of the first mentioned plain "the interior portion is occupied by the natives" (Report of the Board for Studying New Guinea, p. 15). And of the lands around the Sentani lake "a part is inhabited by the natives,"[128] and "apparently kaiñgin agriculture is practiced on a rather extensive scale by Papuan tribes."

These remarks are interesting since they show that in New Guinea as in every other land, if soil and climate produce food and supply other essential human wants, it is inhabited. And the less international commerce there is, the higher the correlation between the density of the population and the productivity of the soil. Probably New Guinea should not be considered as a forgotten little corner of the world. On the other hand it is more likely that in the course of a few thousand years tests of settlement and agriculture have repeatedly been made, but unsatisfactory results have compelled giving up these tests. It would be quite otherwise however if a region is included in world commerce because it can produce high value world products such as Deli tobacco, Java coffee and quinine in place of low value food substances for an authochthonous population. If some day such crops might be discovered for New Guinea, then the whole situation would change. Then the land would blossom; yet it would be no more independent than

127. L. c., pp. 12-21.
128. L. c., pp. 16-17.

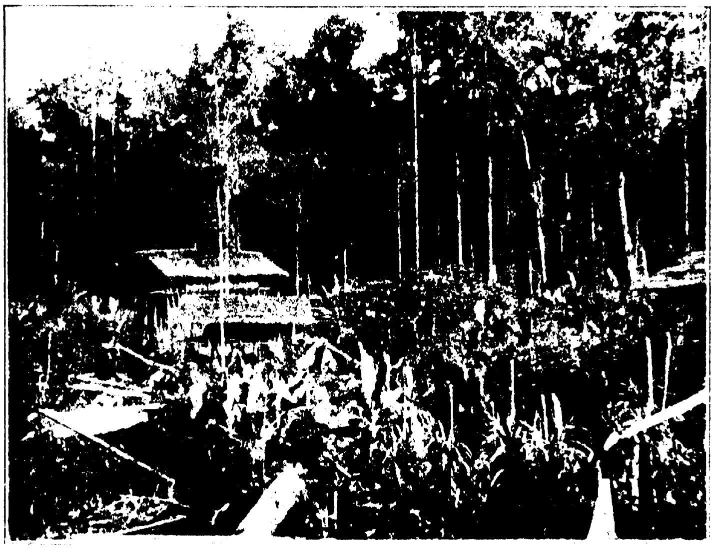


Photo by Gooszen

Fig. 121. New Guinea.--Irsam houses and plantings at Kapoerare, between Etna bay and Geelvinck bay.--High forest with quite a good deal of undergrowth. Soil when used extensively in no sense infertile.

the worm in a gall nut which must perish without the living oak.

The small plains around Geelvinck bay are not well enough known to assign agricultural values to them. It is worth noting that the Study Board[129] recorded that for the first discussed piece of coastal plain "the spate high water mark stood 6 m. above the usual level." If in such a completely forested region such enormous differences in water level can occur, then indeed at times enormous quantities of rain must fall in the back country. This would indicate the presence of low fertility and would not favor a general agricultural development of the region.

In the northern part of the "Bird's Head" there are only small plains. It is possible that the long but narrow plain lying behind Sorong in the direction of the Tamrau mountains will become the best agricultural area in Netherlands New Guinea.

So the number of plains of promise is very meagre indeed. The most southerly, very flat ridge of East Netherlands New Guinea, from the Digoel (lower course) toward Merauke and still somewhat further is promising because of lower rainfall. It is the so-called savanna region. It is true that according to all the information in the literature the soil is poor. But with fertilization and green manuring it may be possible to partially meet this need. It is worthy of note that the regions of New Guinea which are the thickest populated are in this southern strip. The greatest efforts for the improvement of the agriculture of the native population should probably be expended here.

129. L. c., pp. 19-20.

THE AMBOINA, CERAM, AND BOEROE GROUPS: ALSO THE BANDA GROUP

Reports are seldom found in the literature relating to the soils of these islands, in spite of the fact that they are a part of the oldest settlements of Hollanders in the Netherlands East Indies. However, the geology and the climate are rather well known, so that we may deduce something as to the soils.

Soil-Forming Rocks

A. Amboina

This island really consists of two islands: southerly Leitimor and northerly Hitoe, connected by a low, small land bridge. The geological map by Verbeek[1] on the scale of 1:100,000 although made as long ago as 1898, has not needed much improvement. This map furnishes an adequate basis for a provisional sketch of the soil-forming rocks (see Figure 122 below).

Petrographically Leitimor and Hitoe are quite different but rather in a quantitative than in a qualitative manner. Leitimor contains considerable granite (II), especially in the southeastern half of its length. Next to that on the east-northeast, occurs a large area (I) of very basic rocks: peridotite, gabbro and serpentine. Then farther northeast lies a body (III) of sandstone and schists, and still beyond that a somewhat smaller area (IV) of acid eruptive rocks which on the whole may be called liparite. Just west from the granite tract there is some (Ib) peridotite, in part covered over by loose material (more about this later). West from that, (west of Amahoesoe) a region of tuffs and breccias of quartz mica andesite (IV) occurs.

The northwestern lengthwise half

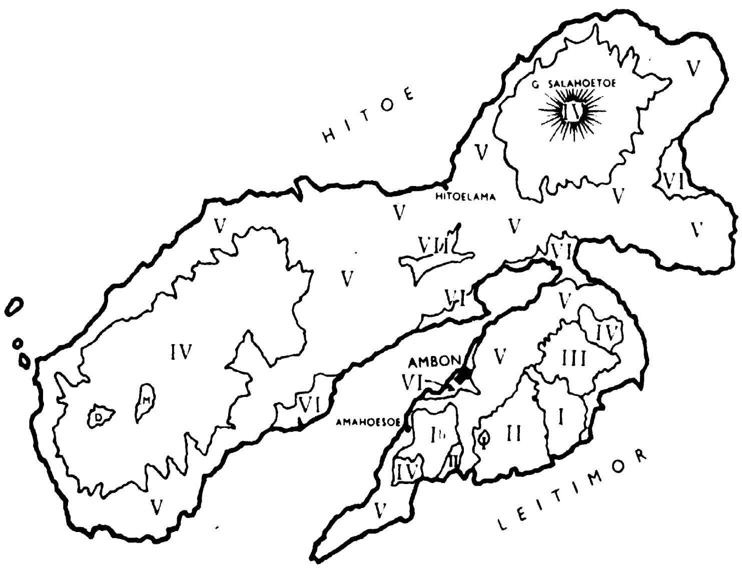


Fig. 122. Sketch Map of Amboina Island, showing the distribution of important soil-forming rocks. --After Verbeek.

1. R. D. M. Verbeek, Geol. beschr. v. Ambon, Jb. Mijnw. N.O.I. (1905), Wet. Ged., 305 pp.

of the island contains the same rocks which have been mentioned. They are at least partly quite deep down and covered over by a younger formation (V), consisting of layers of conglomerate and loose fragments of older rocks lying almost horizontally, alternating with layers of coral limestone. In general the coral comprises less than half of the total. The loose fragments consist of sand with large and small gravel and cobble of quartz, sandstone and eruptive rocks (see Fig. 123, page 298).

According to the map by Verbeek, the larger half of the island, Hitoe, is simpler in its distribution of soil-forming rocks. From this point of view, peridotite, diabase (D) and granite can be neglected. At about 900 to 1,000 meters elevation in the west and in the east the higher portions of mountainous land (IV) consist of liparite and dacite on the one hand, and bronzite andesite and quartz bronzite andesite on the other. Over the lower slopes of these mountainous regions and over the whole central portion between them this same formation (V) of conglomerate and loose fragmental material of andesites and melaphyres (M) extends, sometimes mixed with broken blocks of granite, diabase, and peridotite. Also limestone, including a little soft marl (VII), and coral limestone occurs. All of these except the lime contain detritus from the eruptive rocks.

B. Ceram

If the geological sketch map of L. Rutten[2] is studied with the accompanying description,[3] it will be found that the soil-forming rocks and their distribution are much like those of Amboina, although important differences are to be noted.

As regards the area exposed at the surface, igneous rocks are unimportant. Basalt and andesite are scarce, there is only a very small amount of granite. On the contrary, crystalline schists, both phyllites and mica schists, are very widely distributed and are certainly to be considered as the most important soil-forming rocks, along with the greywacke-slate formation and the Trias formation in Flysh facies (that is to say, it forms a complex made up entirely of tuberous clayshales, sandstones with mica, calcareous sandstones, marls and thin-bedded limestones).

Sedimentary and metamorphic rocks thus predominate, while igneous rocks are scarce and volcanic rocks do not occur. As on Amboina, there are no active volcanoes. Fig. 124 (page 298) shows distinctly the form of folded mountains and ridges without separate cones.

In and upon the Neogene and Recent formations coral limestone is found.

C. Boeroe

Also Boeroe, which has not been adequately surveyed by geologists, appears to consist for the greater part of crystalline schists. Besides these the above-mentioned Trias-Flysch formation occupies an important area.[4] In so far as is known, no soils are derived from igneous rocks; nor do volcanoes come into the picture.

D. Banda Group

In contrast with Amboina, Ceram, and Boeroe, the islands of the Banda group are fundamentally composed of very young volcanic material.[5] Pyroxene andesite, in different, but very closely allied sorts, is the predominant soil-forming rock. In the beginning this was largely in the form of pulverized ash, lapilli and bombs, all of which in numerous places hardened to tuffs and conglomerates. Besides these, there is a little basalt on Neira.

However, in addition, coral limestone entirely covers the lower islands, but it does not completely cover the larger and higher islands, as it never occurs higher than 70 m. above the sea.

2. L. Rutten, Voordr. geol. N.O.I. (1927). p. 732.
3. Rutten, l. c., pp. 721-740.
4. L. c., p. 742.
5. R. D. M. Verbeek, Jb. Mijnw. (1900), p. 17.

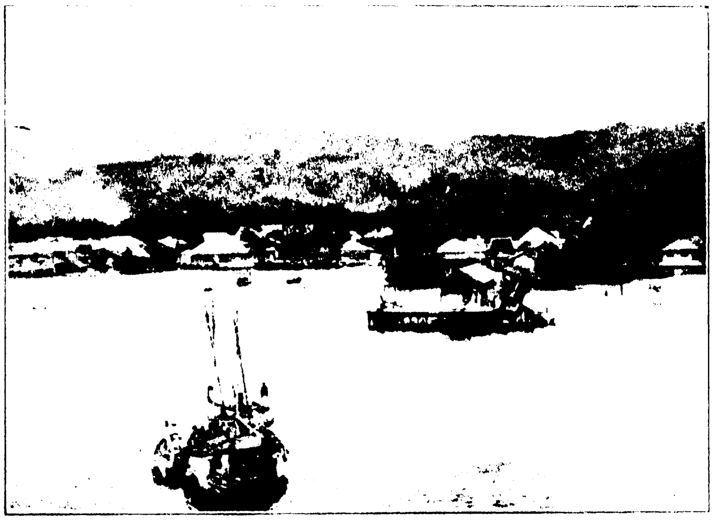


Photo by Aug. de Wit

Fig. 123. Roadstead of Amboina. On the hilly land lying behind the town the miserable, sandy soil with a poor water holding capacity carries a poor vegetation.

Photo by A. L. de Bruijn

Fig. 124. West Ceram. Panorama with camp Honitetoe in the foreground. A succession of folded ridges without separate peaks; not volcanic at all. The entire land covered by tropical high forest.

Climate

The climate of all the islands considered together is truly equatorial. Thus, almost without exception all months of the year average "wet" with more than 100 mm. rainfall. Only a part of northeast Boeroe appears to have a distinct dry period. Perhaps this is, however, to be ascribed as much to definite orographic idea of the distribution of rainfall throughout the year.

If we take into consideration the fact that seldom does the elevation of these islands exceed 1,000 m.--(only a couple of peaks of Boeroe and especially of Ceram extend up above the 2,000 m. level, to a maximum of approximately 2,500 m.) obviously the temperature of the soil is from warm to hot.

Table 70

DISTRIBUTION OF RAINFALL DURING THE YEAR ON SOME OF THE ISLANDS OF THE MOLUKKAS

Place	Location	Height above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Namlea,	Northeast Boeroe	at sea level	16	75	196	200	186	108	116	99	98	53	35	37	47	133	1308	6	4
Kajeli	East Boeroe	"	37	128	214	210	226	171	169	206	171	123	60	47	78	196	1871	9	2
Piroe	West Ceram	7	16	122	271	340	255	232	196	136	161	94	113	97	132	244	2271	10	0
Wahai	North Ceram	at sea level	49	144	287	390	319	211	159	121	106	87	87	92	111	197	2167	9	0
Boelabaai	Northeast Ceram	"	18	121	214	227	253	264	184	165	181	73	92	115	134	192	2114	10	0
Banda-Neira,	Banda	"	52	174	243	201	234	332	392	353	209	105	109	111	129	243	2662	12	0
Manoesela	Central Ceram	about 1000	13	211	229	278	350	351	269	257	192	139	150	148	213	287	2863	12	0
Ammahai	South Ceram	at sea level	48	135	110	108	146	221	370	401	444	369	213	144	105	104	2735	12	0
Elpapoetih	Southwest Ceram	6	17	172	138	163	188	277	335	333	344	255	167	105	109	139	2553	12	0
Honitetoe	West Central Ceram	480	12	189	181	203	212	335	293	352	348	210	192	146	168	191	2831	12	0
Riring	Northwest Central Ceram	700	12	177	300	315	299	369	316	250	154	110	173	199	254	215	2954	12	0
Saparoea		at sea level	49	165	109	110	144	259	516	648	600	427	266	179	101	137	3496	12	0
Amboina	North Leitimor	"	52	199	127	116	134	283	522	641	591	392	240	153	112	130	3441	12	0
Hitoelama	North Hitoe	"	34	127	141	140	161	219	284	353	329	220	106	89	114	143	2299	11	0
Leksoela	Southwest Boeroe	6	16	125	149	157	122	228	420	689	604	294	136	102	83	133	3117	11	0

conditions as, for example, is the case of Paloe on Celebes. However, northeast Ceram never gets as dry as that (Table 70).

Whether the rainfall maximum occurs in the west monsoon (Dec. - March), as is the case on northwestern Ceram, or later (May - July), as on Amboina and southwestern Boeroe, is quite immaterial for the processes of soil development. The principal point is that only in northeastern Boeroe is there a regular annually-occurring drying out of the soil. This occurs on only the convex surfaces, for land in other topographic positions probably receives extra moisture from higher lands having a heavier rainfall. Table 70 gives a general idea of the distribution of rainfall throughout the year.

Weathering Processes and the Resulting Soil Types

A. Amboina

Since there is almost no part of Amboina which has an elevation as great as 1,000 m. and since the rainfall is such that ordinarily there is not a single dry month during the entire year, the weathering cannot exhibit much variation and, with slight variations, it is all of the continuous leaching-out type.[6] As a consequence we can expect to find yellow and brown to red tints almost everywhere on the hills and mountain slopes.

6. Formula (**He** to **Wa**). (**NN** or **nn**) depending upon whether the location is at sea level, or distinctly higher, and whether the weathering product is quite pervious or only slightly so.

As early as 1821 Reinwardt observed[7] that "red earth lay on the limestone of the coral reefs," where small holes held some earth. Sal. Müller[8] recorded that "on the hills and mountains of Amboina, ordinary clay is found most frequently. Many times this is colored red by oxide, more or less mixed with sand." He made no distinction in relation to the parent rock. Nevertheless he did record that "fertile brown garden earth" lay in valleys and on low, flat land where there was more humus and more moisture in the soil. Ludeking[9] described certain features of Amboina minutely but merely mentions "important hills of red clay" behind Batoe merah, and "hills of quartz sand, or indeed hills of white or bluish clay" in the environs of Oerimesing, thus on the northwest corner of the granitic tract (II), lying next to the "gravel formation." Various writers have noted the "deep reddish brown earth" on the peridotite (I).

But according to Gerdessen[10] on Mt. Salahoetoe (IV), in northwest Hitoe there is "heavy yellow clayey soil, entirely different from the red clay lands around Amboina."

While all these bits of information are fragmentary they agree with what we would expect to find: deep reddish brown lixivium on the iron-rich peridotite, pale red and sandy lixivium on the granite, calcareous red earth upon the elevated coral limestone reefs, and mainly red lixivium on the mixed gravelly lands. On the contrary on the acid eruptives of Mt. Salahoetoe, under forest and at greater elevations, "heavy (poor in iron) yellow clay" occurs. Yes, on the peak it is apparently possible that on more nearly level terrain and above 1,000 m. elevation, a subhydric or at least amphibiously weathering soil may develop from the heavy clay, for Gerdessen[11] wrote: "At each step filthy black water bubbled up out of the soil, and only now and then, if the foot tore up the carpet which the roots formed with the chilly moss, was there visible a layer of clayey yellow earth." It is thus only in the uppermost layer of lixivium which contains organic matter that such a low pH can occur that dark water can run out of the soil. A little deeper down the iron has not yet been leached out. However, if Mt. Salahoetoe were 2,000 m. high in place of only 1,000 m., we can imagine how favorable the conditions for peat formation would be. In this connection Verbeek[12] records "on somewhat high mountains a thick covering of moss."

Meanwhile it is safe to accept that everywhere, both upon Leitimor and on Hitoe where the autochthonous soil is somewhat deeper, the faintly humous surface soil and the lixivium lying under it will be quite senile. At least that they are passing through the third, the virile stage. It is thus impossible for the soils to be very fertile. This is in agreement with what Bleeker[13] had written long ago:

"As to the vegetation and the agriculture the conditions of the terrain are in no sense favorable..... In general, the hills are clothed with only scanty vegetation, among which are melastomas, acacias and bracken in several forms and of which in some places there are large numbers. The higher trees are for the most part grouped together in the ravines, where the soil (accumulated by wash?--E. C. J. Mohr) offers a foothold and a greater content of moisture....and the trees can obtain a better supply of food." From what is known about the habitat of such plants elsewhere, the condition of the plants indicates clearly that this soil is not worth much, and only where much moisture is continuously available in the ground is a tree vegetation possible, even though the trees be such as have but modest requirements (see Fig. 123, page 298).

But, on the other hand, because of adequate proportions of iron and sand it

7. Reinwardt's reis i/d Ind. Arch. (Uitgeg. door W. H. de Vriese) Amst. 1858, pp. 426-427.

8. Sal. Müller, Reizen en Onderz. i/d Ind. Arch., (Amst., 1857), II, p. 27.

9. E. W. A. Ludeking, Schets (274 pages!) v/d Resid. Amboina, Bijdr. T. L. en V. van N. I, 3, III (1868), p. 9.

10. L. E. Gerdessen, Tijdshr. v. Ned.-Indië (1871), p. 381.

11. L. c., p. 380.

12. R. D. M. Verbeek, Jb. Mijnw. N. O. I. (1905), p. 38.

13. P. Bleeker, Reis door de Minahassa en den Molukschen Archipel (Batavia, 1856), II, 59.

may be easily accepted that physically the soils of the hills and mountains of Amboina are not so bad. They are only poor chemically, and with a low humus content they do not retain sufficient moisture. On Hitoe,--and the same is apparently also true for Ambelau island (SE of Boeroe), and Haroekoe, Saparoea and Noesa Laoet islands (east of Amboina), whose soil-forming rocks belong to the same group of more or less acid, iron-poor eruptives as those which are the most important on Hitoe,--it is however possible that if the tropical high forest should be cut down, and the surface soil washed off, an impoverished, pale, plastic clay subsoil would remain behind. Physically, this would be far from excellent. Hence, here on Hitoe, it is thus still more necessary than on Leitimor to guard against deforestation.

B. Ceram

Also on Ceram, on sloping or convex land, because of its position and topography, the weathering is especially of the leaching-out type [(**He** to **Wa**).(**NN** or **nn**).**ae**] with the assistance of air, while in the low and flat portions it is of the leaching-out type which is periodically or continually without air [**He**.(**NN** to **nn**).(**am** or **aq**)].

Under these conditions, on the hilly or convex parts the mica schists produce a soil which is pale yellowish-brown in color. The surface soil contains a little organic matter and is somewhat darker, but deeper down it is a more plastic lixivium still containing flakes of mica. Still deeper, especially as one goes somewhat higher to more than 1,500 or 2,000 meters, amphibian conditions gradually come in. The effects of such conditions are recognizable on a profile wall by a spottedness,--brown threads and bands against bluish gray, bleached patches. If at an elevation of more than 1,800 m. flats occur, and more especially if there are surface depressions, the conditions may perhaps become more extreme, even to subaqueous weathering, with the formation of peat on the surface. In either case the soil would have a quite strong acid reaction.

The phyllites and glistening slates (schists ?) apparently produce a somewhat darker soil type, but even so it is no crumbly, pervious earth, which if more or less senile in the third to fourth stage, would become brownish red to red at only a little distance below the surface. On the contrary, these rocks almost always produce a brownish yellow type of soil. However, weathered rock fragments are often present which give the soil a grayish brown color (second stage of weathering).

On the basis of a few observations Rutten[14] described Ceram and also recorded a number of interesting statements relating to the agriculture, etc. He comments: "Some rocks, belonging mostly to the Mesozoic, and the soils above them, have a tendency to flow downward when saturated with water during long-continued rains." This phenomenon has already been discussed in a general way (pages 177-178). It is obvious that serious erosion and even avalanches are the consequences. Therefore, only in particular cases can such a soil become deep when on slopes. But then such soil seldom becomes senile. On the contrary--if the slopes are even but moderately steep, as is more often the case in Western Ceram, the bare rock is frequently exposed at the surface.

On the greywackes, on the sandstones, and on the sandy and non-sandy limestones there are many different kinds of soils. However, with the continuously wet soil climate, all are continuously leached. This is true whether under subaerial or amphibian and subaqueous conditions. No concentration of soluble constituents can occur. At the most, iron concretions and illuvial layers of ore can occasionally form under amphibian conditions. In the quotation referred to, Rutten makes no mention of them but says: "If, in general, one may characterize the soils of Ceram as chemically poor, yet it would be premature to state that they were unsuitable for crop production, since the suitability of the soil for agriculture is determined not only by chemical but also by other factors, among which is the physical constitution of the soil....."

Without doubt, soils are to be

14. L. Rutten, Ontwikkelingsmogelijkheden van het eiland Ceram, T. K. Ned. Aardr. Gen., 37 (1920), pp. 43-73, and especially pp. 51-52.

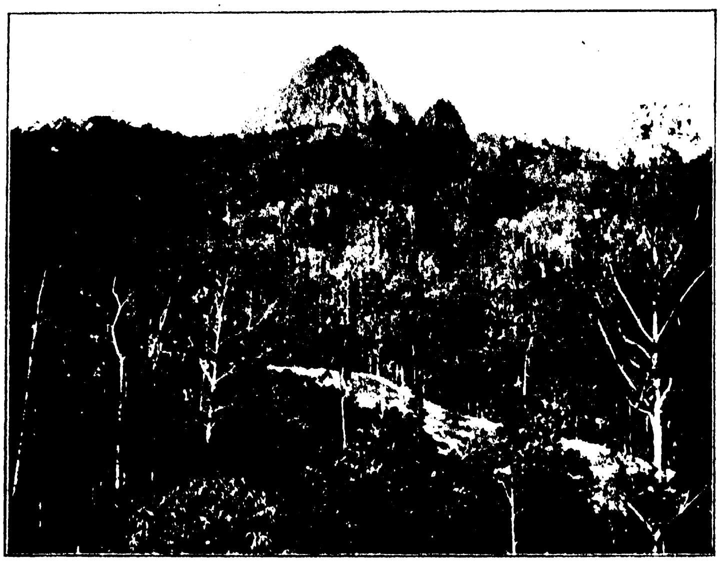


Photo by K. Martin

Fig. 125. North Boeroe. The limestone peak Kakoesan.--Very rough mountains of sedimentary and metamorphic rocks. Forest with many tall straight boles and little undergrowth on poor, thin soil. A kaiñgin, which after 1 or 2 years will be abandoned.

found on Ceram which are physically good, for example, on the sandy limestones, and mica schists. But apparently there are still many more of the heavy, impervious soils without adequate aeration. These will be found especially in the low plains, which have been built up by allochthonous material from higher regions. Running through the plains here and there will most certainly be a few banks of coarser sand and sandy ridges and even gravel banks. From the nature of the rocks it is to be expected that fine textured heavy alluvium will predominate over coarse colluvium. But along the sea shore the soil will be principally sandy, with even cobble stones here and there.[15]

C. Boeroe

Much the same is to be said about Boeroe as of Ceram. The only exception is that it is possible that blackearth [al-He. nvv.am.3] has developed on the point near Namlea. The dry season of 4 months and the parent material (such as weakly convex sheets of alluvium) are favorable for the development of this black soil. Irrespective of the origin, heavy, impervious clay must be present. The only opportunity for such a soil to develop on Ceram is probably on the northeast coast of Hoalmoeal.

Regarding the flora of these islands Beversluis[16] records a few particulars which are pertinent here. Speaking of "the always green tropical high forest" of the Molukkas proper "wherein the highest story is formed by giant forest trees which are 40 to 60 m. or sometimes still higher" (see Fig. 125 above), he considers that this forest mantle has as yet been but little damaged by man. First, because there are not many inhabitants, and second, because the regular rainfall makes forest fires impossible. Thus a mixed forest exists, but the very tall giants of the forest are quite probably dammar trees, which many other authors have recorded as being numerous on the above-

15. Cf: A. J. Koens, Alg. Lb. Weekbl. (1920), pp. 1159-1162.
16. A. J. Beversluis, in: Beversluis en Gieben: het Gouvern. der Molukken (Batavia, 1929), p. 47.

mentioned islands. As a rule dammar trees are not a sign of great fertility of the soil nor does the scant population and its only slight inclination toward kaingin cultivation indicate marked soil fertility.

As to the islands lying farther to the south with a stronger east monsoon, Beversluis styles the so-called monsoon forests "thin and with certain predominant sorts of trees," among others "the Eucalyptus forests of Southern New Guinea and a few other islands." This turns the thoughts involuntarily to Boeroe, and also to Namlea, and the question comes to mind as to whether the cajiput (Melaleuca leucodendra) trees also occur on Boeroe in such associations.--It is notable that civil administrator Schmid[17] expresses himself thus on the subject: "There, where the cajiput tree grows, the land is distinguished by barrenness, since besides this plant only cogon (Imperata spp.) remains alive, all other vegetation having perished."--Beversluis[18] describes the cajiput forests of Boeroe and West Ceram as similar to thin pure birch forests (see Fig. 126). There can be but one conclusion; a pure stand of one kind of forest tree indicates a poor soil.

D. Banda Group

On Lonthor and Neira islands which are largely made up of loose volcanic products, often black in color, the finer ash is completely "weathered to brown clay."[19] Hence this soil must be a juvenile brown lixivium from andesitic or basaltic efflata [V.b.I--He.NN.ae(2-3)]. Mt. Api, on the contrary, is younger so that it is not yet so much weathered; the soil is at most in the first to second stages. Therefore the soil on this mountain is not yet a distinct brown, but it is still gray and extremely pervious, holding little water. As a consequence, it is only scantily covered by vegetation[20] (see Fig. 127, page 304).

Photo by W. Docters van Leeuwen

Fig. 126. Amboina. A small forest of Cajiput (Melaleuca leucodendra) on dry gravelly land.

Evaluation and Utilization of the Soils

Before going into detail, in order not to repeat, let us record a couple of general remarks applicable not only to Amboina, Ceram and Boeroe but also to many other islands of the Molukkas.

If in astonishment one asks why so little comes from "the great East," in spite of the fact that the Hollanders have

17. H. C. Schmid, Kajoepoetih-olie, Teysmannia, 25 (1914), p. 34.
18. L. c., p. 48.
19. Verbeek, l. c., pp. 4 and 6.
20. Compare: Bleeker, l. c., dl. II, p. 240.

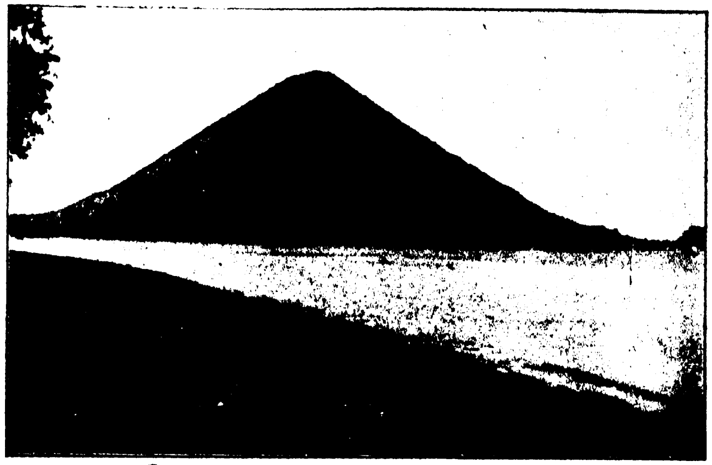


Photo by H. J. Lam

Fig. 127. Banda Islands. Mt. Api, whose upper slopes are bare, has more vegetation lower down.--In the foreground: beach of Groot Waling on Lonthor. Black, basic volcanic sand with coral fragments.

been settled here the longest (already more than three centuries), the answer may be given in these words of Broersma:[21] "The great fault has been the over-rating of the value of the soil in the Molukkas, an error which has continued down to the present time."--And Beversluis[22] also shows the situation in its true light when he says: "If one leaves out of account the planting of coconuts and the cultivation of a few fruit trees by the natives, and takes into consideration the fact that nutmegs and cloves are planted and raised as purely forest crops, then one must recognize the sad fact that there is almost no native agriculture. It is true that the natives plant crops for their own food, yet hardly systematically.

The reason for this is the nature of the scant population, which "has almost no needs." And also "because this population can easily obtain its food from the wild sago palm," and furthermore "the agriculture on the extremely poor soils in this province demands much difficult work." And even such effort gives only a moderate or poor yield, not at all proportional to the exertion necessary to produce it. It is just another case where there is never a long dry season--the so-called "continuing fertility" is lacking. This lack can really be remedied only by active, young volcanoes. If the soils are fertile then the inhabitants are industrious. If on the other hand the soils produce but little, then people would indeed be foolish to make a living by the sweat of their brows, when with much less exertion they could live frugally, but equally well, upon the starch from the sago palm.

With these general points of view in mind, let us now consider the separate islands.

A. Amboina

Because of the almost entire lack of paddy fields and other cultivated land, this island cannot help but make an astonishing impression upon anybody who comes directly from Java (see Fig. 123). Since the rivers are short and thus have no regular flow, irrigation from them is uncertain.[23] It is thus understandable that

21. R. Broersma, Koopvaardij in de Molukken, Kolon. Tijdshr., 23 (1934), p. 331.

22. Beversluis, l. c., p. 87.

23. Bleeker, l. c., II, p. 152--briefly characterizes Ambon as "unsuited for lowland rice cultivation."

there are no paddy fields. For paddies are dependent upon the rain. Also the soil is either too pervious, or, where it is able to hold the water, it is too senile and too poor. Moreover upland, unirrigated, annual crops do but moderately well. In a word: Amboina seems more suited to shrub and tree crops. Experience points to the same conclusion.

The small flat areas (VI), the so-called "pantai lands," unimportant on Leitimor, are of somewhat greater extent upon Hitoe. On the lowest marshy spots of these lands grow sago palms, while coconuts occupy the well drained parts. On higher land, on the slopes of hills and mountains, are nutmeg and clove trees, although they were more frequent in earlier times. Upon the "loose coarse soils" between Soeli and Toelehoe[24] there are some small groves of cajiput (Melaleuca leucodendra) (see Fig. 126). Teak also grows there. Apparently there are not many different types of soil. At least we find almost nothing concerning them in the literature.

In his description of Amboina[25] Verbeek records that the Binongkonese prefer a calcareous soil for their vegetable and fruit gardens in which lime fragments are mixed with fragments of eruptive material. "But, since this land is not especially fertile, these gardeners move rather frequently, they are slowly clearing the heavy forest. In the neglected kaingins cogon (Imperata spp.) is the only thing which grows....."

Summarizing the above, we cannot expect[26] that Amboina will become a rich agricultural region, although there are, of course, all sorts of ways in which it may be improved. On all lands which have been once deforested and upon which tree crops are to be planted, successful results are certainly to be expected from green manures. But as to which particular kind, is a problem for the agriculturists. Meanwhile, it appears probable that the selling price of the products must be sufficient to make possible the use of imported fertilizers and hence to significantly increase the productivity of the soil.

B. Ceram

In comparison with the other islands, most of the low flat plains on this island are along the coast and extend more or less into the interior. Hence the extensive sago palm forests are so great that sago can even be exported. If this palm were regularly cultivated and if there were technical improvement in the preparation of sago, without doubt the yield could be notably increased. Along the sandy coast cocos now grow everywhere. Although there are no data as to yield per tree, the production is probably not high. It is worthy of note that in a large number of photographs of Ceram and of Boeroe, in which coco palms may be seen, it is my impression that unusually few nuts can be seen on the palms. This might be an accident, but it may also be a generally-occurring phenomenon.[27]

On Ceram, according to Rutten,[28] cocos grow well almost anywhere on the flat lands and even in the lower mountains but "though the tree may grow everywhere, the yield varies widely in different places." For example, on Elpapoetih bay, on the west bank of the Wai Roeisi river, there stands a small grove of tall, quite old trees, bearing scarcely a single nut. Here the subsoil consists of layers of sand of unknown thickness, which is covered by only a thin layer of "soil," frequently not even a half meter thick. For coco palms, one-half meter of earth is hardly generous, but on many coral islands there is not even that much soil available for the trees, and still the trees bear quite well. Thus there may, possibly, be something wrong with the trees, which inhibits the development of nuts. Also in Palembang, along the Moesi, there are many tall,

24. Bleeker, l. c., II, p. 165.

25. R. D. M. Verbeek, Jb. Mijnw. (1905), Wet. Ged., p. 10.

26. Compare: Beversluis, l. c., pp. 79-80; among others this sentence: "In connection with the good physical condition of the forest soils agriculture on these soils might give favorable results for a short time; although in the course of time disappointment cannot be prevented."

27. When considering the case of Bangka this phenomenon will be mentioned again.

28. T. K. Ned. Aardr. Gen., 37 (1920), p. 55.

practically sterile coco palms. They are growing in a soil known to be poor in phosphorus. Can it be that there is also a lack of this element on Ceram? Analyses of this Ceram soil have not been available.

And as to rice:--"there is no systematic cultivation of paddy" in the Amahei subdivision, reported the old administrator Tichelman.[29] But still, whenever and however rice is planted, it grows quite well. It does not, however, yield anything like a hundred fold; normally only a 20-fold harvest; while 30 to 40 fold is considered especially favorable. If it be taken for granted that approximately .65 quintals of seed rice is sowed per Ha, this would make the "normal" yield about 13 quintals per hectar. This is considered as a poor yield. As to how unimportant rice is as a cultivated crop on Ceram is quite evident from the relatively few lines devoted to that crop in Mededeeling 29 of the Encyclopaedic Bureau of Batavia (1922).

Rutten[30] considers that not only "can the soils of Ceram best be compared with the soils of Java on which are located the poorest paddy fields, but also not much benefit can be expected from the irrigation water of Ceram."

"Young volcanic rocks are almost entirely lacking on Ceram. Elsewhere in the Archipelago they give rise to the most fertile soils and the richest irrigation waters. It is therefore very probable that the irrigation water from the large rivers of Ceram will be found to be very poor in plant food constituents."[31] Furthermore, per unit of area there are not enough laborers, which condition also is indirectly connected with the low productivity of the land. Other factors, however, have an influence upon the density of the population. It is possible that in some distant future time an extensive rice culture of the sort found in Burma, Thailand (Siam) and French Indo-China will also develop on Ceram.

C. Boeroe

Boeroe is another island which has no true agriculture. The same things may be said about its soils as have been said about those of Ceram. There is, perhaps, somewhat more limestone on Boeroe and there are more steep slopes and more eroded, bare rock precipices.

"There is no other evidence of the mysteriously fertile soil to which Hollanders wished to go, than a growth of forest which is just as low in vigor as that on most of the other Molukka islands. The only thing which grows especially well on Boeroe is the cajiput tree (Melaleuca leucodendra), which grows with a scraggy leanness in the plain,...." so writes Broersma.[32] On Ceram the cajiput is found only on the peninsula of Hoalmoeal, which lies closest to Boeroe. Perhaps there is also a climatic factor (drought) concerned.

But as to that I cannot say, not having been able to personally visit the islands in question, and not having found in the literature anything of consequence about Boeroe. A single photograph of the landscape (see Fig. 125) may, however, give an impression of this island, which while certainly very important scientifically, is of but little economic significance.

D. Banda Group

Only a few islands of the Banda group have been populated and cultivated; the rest are practically uninhabited. These few islands are: B. Neira, Lonthor, Ay, Rhun and Rosengain. Of these, the last three will not be considered here. The volcanic island Goenoeng Api for the most part is barren and without inhabitants or vegetation. The soil holds no water and is still in the first weathering stage between fresh ash, from which it originated, and juvenile soil. Below, close to the sea are a few spots a little more weathered. Finer material has been washed onto these places from above (see Fig. 127).

The soils of Lonthor are passing through the juvenile and virile stages and are in a high state of fertility. Tropical high forest has all disappeared; the whole island, as far as the soil is suitable, is occupied by nutmeg plantations, with

29. G. L. Tichelman, T. K. Ned. Aardr. Gen. (1925), p. 693.
30. L. c., p. 61.
31. Rutten, l. c., p. 52.
32. R. Broersma, l. c., p. 337.

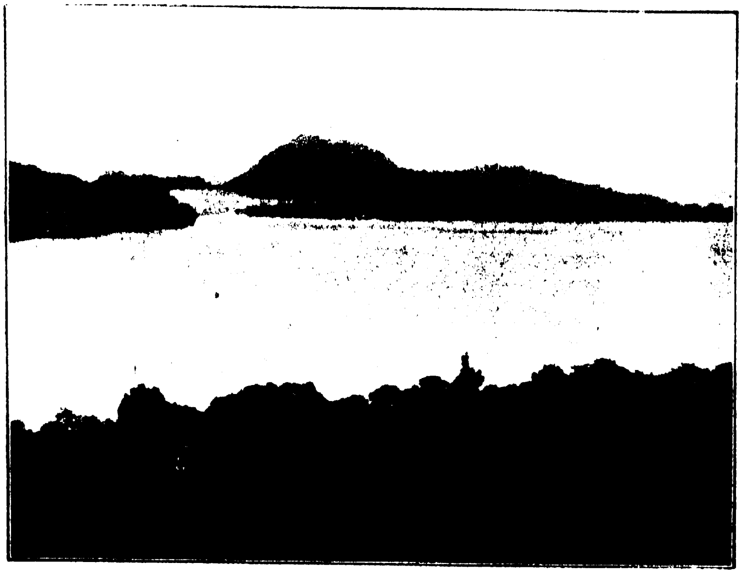


Photo by H. J. Lam

Fig. 128. Neira and the Zonnegat, from Oertatan on Lonthor, Banda Islands. Foreground the luxuriant forest (with Canarium trees) on Lonthor. In the distance to the right, Neira, entirely forested; to the left, the foot of Mt. Api. (See pp. 299 and 303.)

canarium trees scattered among the nutmeg trees. There are historic reasons for the condition of this island being as it is. But this is hardly the proper place to discuss this point.

The yield per tree and per hectar of these nutmeg forests--one cannot really call them plantations--is certainly less than that of the plantations in Central Java. But since the total production of this spice is already equal to, or greater than, the world demand, for the time being there is no point in increasing the yield. Consequently these forests are managed as extensively and as cheaply as possible. There is neither cultivation of the land nor fertilization. The only things which are done are the harvesting and preparation of the products, nutmeg and mace.

Neira Island which at one time, except for the town and the immediate surroundings, was mostly covered with nutmeg trees, now is being cultivated to produce fruits and vegetables for the inhabitants of the town. However, there is no striking increase in the population, for there is no back country. Hence there is not much promise of improvement in the future.

If nutmeg culture becomes less profitable, then perhaps there will be even better prospects for the gradual conversion of a part of the nutmeg forests into clove plantations. Moreover, the soils of Banda are so much more fertile than that of the other, previously described islands of the Molukkas that there will always be a wider range of crops to choose from.

* * * * *

HALMAHERA

Soil-Forming Rocks

If one sets out to write something about Halmahera, he at once notices how little is known about this island; at least how little is published with reference to its agriculture and to its soils. If it is also kept in mind that for more than 300 years the old Hollanders have been in close touch with Ternate, which is in the near neighborhood, this can only increase the astonishment that we know so little about

Halmahera. Involuntarily the question then arises: why in the time of the East India Company did the East India navigators sail only to Ternate, Tidore, and Banda and neglect so many other islands, such as Halmahera?

It is easy to reply that they came for the expensive spices, but this raises other questions, for example, why then could they not obtain just as good spices on all the other islands? and if not, why not?--As yet these questions have not been adequately answered. It is inadmissible to suppose that it was simply because they landed only on those small islands where there were the most suitable harbors. Of course they had information from elsewhere, hints from people who, themselves, or whose navigators already had seen more of the Archipelago, and gave advice upon the basis of their experience. We must thus accept the theory that in previous ages a few islands produced important quantities of spices, and that these islands were surrounded by many others where none were grown. This will also be true for the future, at least for the generations now passing. Consequently the first-mentioned islands had something to offer, which the latter, including the greater part of Halmahera, lacked. This valuable something was, and still is today, volcanoes.

Ternate, Tidore, Banda--all three of these are young, still active volcanoes, with ash and tuff on the flanks, weathering to young fertile soil.

If we look at map II accompanying Verbeek's Molukka report,[33] the following features of Halmahera are conspicuous: The backbone of the southern, the southeastern, the northeastern, and the smaller northern point of the northern peninsula consists of similar kinds of "old basic eruptive rocks" (= obe on the sketch map). The broader part of the northern peninsula is something else. Along the western side and on its northeastern point this region has a series of about half a dozen volcanoes. Continuing southward is a second series, which includes Ternate and four other smaller islands. In addition, the broader part of the southeastern portion of the northern peninsula consists of a quite extensive mountainous region (t), as well as the plain of Kaoe (a), formed

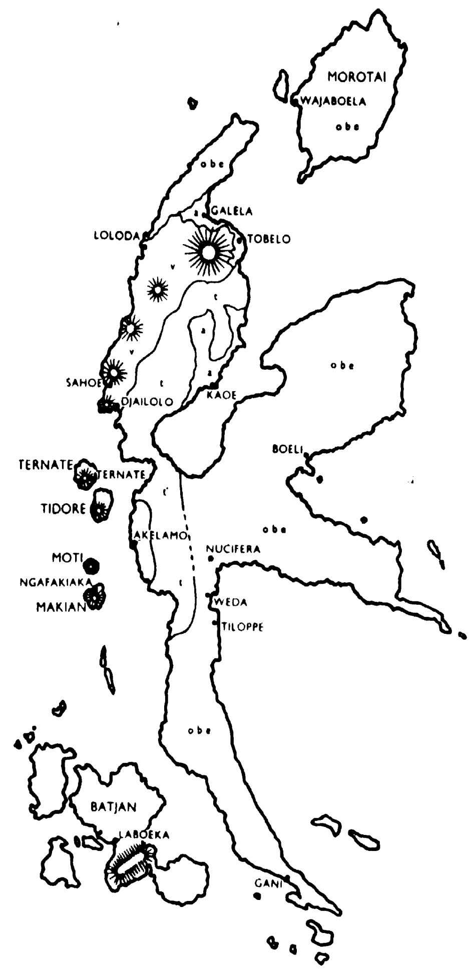


Fig. 129. Sketch Map of Halmahera showing the distribution of the principal rocks.--After Verbeek.

Legend:
obe = old (basic) eruptives
t = (older) tuffs
v = (younger) volcanic products

principally of, and covered over by, ejecta from the chain of volcanic peaks lying to the west (t). A similar covering with volcanic materials (t) continues southwards. Here, however, the volcanoes are somewhat older, and extend to the center of Halmahera and even on into the base of the southern peninsula.

The above-mentioned old basic eruptive rocks are composed of diabase and diabase porphyrite, gabbro, peridotite,

33. Jaarb. Mijnw. N. O. I. (1908), Wetensch. Gedeelte.

Table 71

DISTRIBUTION OF RAINFALL THROUGHOUT THE YEAR FOR HALMAHERA AND ADJACENT ISLANDS

Station	(Location)	Elevation above sea level in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Gani	South Halmahera	--	12	99	106	119	203	152	141	204	174	125	110	64	67	89	1554	9	0
Laiwoei	(Obi)	--	15	117	159	133	195	150	160	160	174	107	96	33	75	123	1564	9	1
Laboeha	(Batjan)	--	44	126	179	153	155	173	150	150	146	123	100	88	113	168	1698	11	0
Akelamo (branch)	West Halmahera	at sea level	6	134	138	142	125	244	215	328	245	161	259	192	127	198	2585	12	0
Akelamo	West Halmahera	0	12	126	135	141	148	274	258	240	179	131	170	136	135	154	2101	12	0
Ternate		--	52	150	209	185	198	231	243	209	133	105	110	133	199	227	2175	12	0
Djailolo	West Halmahera	7	17	150	174	170	170	232	301	240	156	113	167	193	178	203	2315	12	0
Loloda	Northwest Halmahera	60	12	117	254	126	176	263	240	231	159	69	135	130	199	189	2171	11	0
Wajaboela	(Morotai)	--	12	114	241	178	200	181	165	145	104	87	90	90	156	203	1820	9	0
Tobelo	Northeast Halmahera	--	23	144	161	179	196	206	216	225	156	120	142	139	158	155	2054	12	0
Kaoe	Northeast Halmahera	--	9	148	174	125	163	163	152	225	78	86	132	100	160	202	1780	10	0
Boeli	East Halmahera	2	12	150	201	224	198	237	275	378	233	178	165	110	185	199	2553	12	0
P. Ingelan	Southeast Halmahera	2	6	135	160	222	239	185	220	244	243	157	134	95	134	151	2184	11	0
Nacifera	Southeast Halmahera	0	9	140	175	166	120	140	196	449	448	422	192	72	94	76	2570	9	0
Weda	Southeast Halmahera	2	12	144	164	140	170	172	189	391	366	294	171	103	114	117	2592	12	0
Tilope	Southeast Halmahera	1	9	122	114	131	197	180	269	433	470	341	186	92	104	106	2625	11	0

and serpentine. According to more recent investigations of Brouwer,[34] there should also be included more acid rocks such as granodiorite, diorite, quartz porphyry, dacite and andesite. On these, here and there, especially on the northeastern and southeastern arms, lying more in a zone around the foot, is a covering of Miocene limestone and marl. The younger volcanic rocks (v) are basalts and andesites. Among the latter several are quite pale and acid.

Thus it is that Verbeek says:[35] "The conclusion to which my investigations have led me is that the geology of Halmahera must be called fairly simple."-- Taken by and large he is certainly correct.

Climate

So long as one does not go into details, the climate is also simple. Halmahera lies under the equator, so that the temperature oscillations of the monthly averages throughout the whole year are minimal. At sea level the daily maximum temperature is about 28°C and the minimum about 22°C, with a variation of 1° to 2°C for each.

Halmahera is not high. In the broad part of the northern peninsula the volcanoes rise above the rest of the island, and in Mt. Gamkanora reach 1,635 m.,[36] the highest peak of the island. The rest of the mountainous land lies almost entirely below 800 m.; perhaps only a single mountain peak is higher than that. Apart from the volcanic peaks mentioned above, a minimum temperature of no lower than about 16° to 17°C would be an unusual thing.

Regarding the rainfall in general, Braak says:[37] "The Australian rain type does not extend as far as Halmahera; in both monsoons the rainfall is equally strong." This signifies that both monsoons begin with increasing rainfall and end with a gradual lessening of rainfall, as can be seen from Table 71 above. These data have been borrowed from the oft-mentioned source[38] and, in so far as has been possible, have been extended by recalculating the data for 1929-1930. The data for subsequent years have not yet been published.

The data for three places, for which observations were available for only 2 years, were not incorporated into

34. H. A. Brouwer, Jaarb. Mijnw. N. O. I., 1921, Verh. 2e Ged., pp. 15-16.
35. L. c., p. 157.
36. Meded. Encyl. Bureau, Batavia, XIII (1917), Halmahera en Morotai, pp. 18-34.
37. C. Braak, Klimaat van Ned.-Indië, II, (1929), p. 489.
38. J. Boerema, Verh. Kon. Magn. Meteor. Obs. Batavia. No. 24 (1931).

Table 71. On the other hand, data from a few stations on surrounding islands have been added in order that the picture may be made more complete. The order in which the stations are listed in Table 71 is as follows: first, those of the southern tip, then Obi and Batjan followed by the stations along the west coast to Morotai, returning along the east coast to the starting point.

The following general deductions may be stated: there is not a single place on Halmahera which has an average monthly rainfall of less than 60 mm. rain, and of the places with averages for 17 year's observations or more, there is no single month with an average of less than 100 mm. These facts point to a "continuously wet soil climate." This may be considered to be the case in the long run but it is far from being true from year to year. This is clear, for example, if one compares the rainfall figures for the years 1929 and 1930 for Ngafakiaha, on Makean Island, which lies south from Ternate. The figures are presented in Table 72.

figures for Ternate (50 years observations). From this it appeared that only once did a "dry" period occur as long as 4 months (July-October). Seven times there were periods of 3 months as follows, 5 times during (July-Sept.), once during (Aug.-Oct.) and once in (Oct.-Dec.). Thus during 50 years there have been only 8 years during which continuous dry periods occurred at least 3 months long with less than 60 mm. rainfall per month. Hence, for Ternate, one need not hesitate to accept the averages which are given in Table 71 as indicating the actual conditions. The few divergent years cannot affect the average values. The climate of Ternate is "continuously wet"; this is also true of the soil climate. For Halmahera it is difficult to accept anything else as being the case.

Ways in Which Weathering Takes Place and Resulting Soil Types

Since the climate on Halmahera is

Table 72

RAINFALL DIFFERENCES FOR TWO CONSECUTIVE YEARS

Ngafakiaha (Makean)	Elevation above sea level in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
1929......	15 m.	1	116	133	313	837	201	863	1507	356	196	724	228	723	455	6536	12	0
1930......	15 m.	1	54	515	190	66	316	408	255	10	75	0	80	0	0	1915	5	4

From these figures (Table 72) it is evident what enormous differences may occur from year to year. Hence, it is obvious that in order to be able to arrive at useful averages one must have at his disposal series of figures for many years. Thus where such great differences occur as are shown in this table (Table 72) it is more prudent to use the figures of the separate years than it is to use the averages. For that matter, the Encyclopaedic Bureau in its treatment of Halmahera remarked[39] how strikingly "irregular the seasons are in their behavior."

In order to illustrate this further, I went over the annual rainfall

continuously wet, there is little else to be expected than that the soils are subject to continuously leaching-out weathering. The parent rocks, both the older eruptive rocks and the younger volcanic ones, tend especially to be basic and rich in iron. Still it certainly cannot be accepted that all rocks have an adequate iron, calcium, and magnesium content to insure the development of good, pervious weathering earths. (NN will certainly greatly predominate over nn.)

As has already been said, Halmahera is not high; as a consequence, for the most part the temperature is continuously hot and warm. Temperate conditions

39. Meded. Encycl. Bur., Batavia, XIII (1917), p. 12.

can seldom occur and it is never cold at all. Even in the tropical high forest[40] surface soils (**O** or **oE**) rich in humus seldom occur.

Whether the soil is shallow or deep depends upon two factors: (1) the topographic situation, and (2) the nature of the parent material. That is, whether this material is loose and porous, such as young ash, tuffs and porous rocks, or whether it exists as compact solid rock.

Where loose material occurs in a relatively flat position the weathering and soil formation keep well ahead of erosion. But where solid rocks are on steep slopes, even on untouched terrain the soil washes off as fast as it is formed, and no deep soil can develop. But in the latter case, what washes off is certainly good soil material, so that where it can collect, as in a small or large plain, it undoubtedly makes fertile alluvial deposits.

Thus the differences between the northern peninsula (especially its enlarged portion and the connecting isthmus toward the south-southwest) and the rest of the island arise. If there were but more level land adjacent to the rough ridges, this remainder should be able to develop and retain excellent secondary soil types. The only place where a little flat land occurs is the Kobe plain to the north of Weda. From the rest of the old eruptive mountains just about all the weathering material goes directly into the sea.

There is thus left for consideration the young volcanic region, consisting of volcanic mountains and lowland. For the name of the soil type on the slopes of the volcano, andesite lixivium (**V.b.I.--(He to Wa).NN.ae**) may be suggested. As to the stage of the weathering, it depends upon whether there is more brown (stage **2-3**) or more red lixivium earth (stage **3-4**). Presumably brown to brownish red greatly predominates, while on and around the youngest volcanoes, as between Galela and Tobelo, where the stage varies between fresh and virile, the color must vary from a very juvenile gray to a brown.

In the last-mentioned locality there are also substantial bits of plain whose soil has been formed directly from fresh or nearly fresh efflatas. If they lie high enough to be well drained, subaerial soil forms (**V.b.I.--He.NN.ae. (2-3).**) occur but when they have been submerged under water, bluish gray, frequently sandy, subaqueous kinds of soil (**V.b.I.--He.NN.aq. (I-2).**) developed. Where amphibian conditions prevail, soil conditions that are transitional between these distinct groups will occur. They will show the brown veins and flecks which are characteristic of such conditions.

However, where the soil was not developed directly from fresh efflatas, the material washed on was already more or less a product of weathering and this material, upon becoming a new parent material **[V.b.I.--Wa.NN.ae.(I-2)]al-** , was subjected to amphibian or subaquatic conditions.

The largest lowland of Halmahera, the Kaoe plain, as well as the flats between Galela and Tobelo have been formed in this way, hence the same soil type formulas apply to them.--

* * * * *

Most curiously the first and almost the only descriptive writings which were found relating to the soil of Halmahera are dated 1849. T. J. Willer[41] in his "memoranda regarding the northern peninsula" records the following about the Sahoe plain north of Djailolo: "The soil is somewhat friable, yet as a whole pretty fertile and blackish to a depth of 2 ft. Below this the color becomes more yellowish. At a depth of from 3-4 ft. one strikes sand." --This is entirely in agreement with the description and the formula which was given for this region.

Further on, with reference to the plain of Kaoe, Willer states: "The plain ....is so densely covered with heavy forest that there is not any open land worth mentioning. Along the river, as far back as a day's march from the coast, the soil is tolerably solid, while farther inland

40. In the Vervolg. Mem. v. Overg. v. Res. W. A. Hovenkamp (April 1931) we read on p. 9 of Bijl. VII: "For that matter one seldom finds thick humus layers."

41. T. J. Willer, Indisch Archief, Batavia, I (1849), pp. 343-398, especially pp. 346-347.

the soil becomes so soft that the Halfoers themselves cannot clear it. In these marshes are very luxuriant and very extensive sago forests. The nature of the solid soil is just the same as at Sahoe, black, loose and productive down to 2 feet. Under that it is yellowish and poor, with sand and much water occurring at 4 feet."

Possibly that sago palm tract was once a lake or a lagoon which for the greater part has been silted up. The soil described may quite well be a transition from subaerial toward amphibian and subaqueous forms, but at the same time it corresponds with what, according to the parent material and the climate, one would expect.

In conclusion Willer states: "The soil of the important Galela plain differs little if at all from that of Sahoe." Approximately 30 years ago at Buitenzorg I received samples of soil from this plain. They consisted of beautiful brownish yellow lixivium, an excellent agricultural soil.

We must not fail to mention the garlands of reef limestone and other marine limestones on the flanks of the higher mountains. Since there is no record of true marls, we may take these to be limestones, whether they are contaminated or not with more or less older eruptive, young volcanic material, or tuffs.

With the generally prevailing weathering conditions of continuous leaching with warm water in the presence of much air, as well as with carbonic acid in the water percolating down through the earth, the calcium carbonate cannot but dissolve and disappear. The only effect which we can expect from the $CaCO_3$ is that on the limestone mountains the soil will be somewhat redder, a "terra rossa" or red earth from limestone.

Evaluation and Utilization of the Soils

Where approximately 20,000 square km. are inhabited by only about 60,000 people, who for the most part are still very primitive Alfoers, (at least primitive in the field of technical agriculture), it is hard to expect the habitants to properly utilize the soil, and much less to have an accurate evaluation of it. Already approximately 50 years ago Campen[42] wrote: "The agriculture on Halmahera is still carried on in the stage of early childhood"; and in 1917 the Encyclopaedic Bureau[43] arrived at conclusions which differ but little from Campen's view.

With regard to agriculture, the northern peninsula is still the most important. This is not to be wondered at since that is the place where young volcanic soil types are to be found. And yet in spite of this the agriculture even here has not yet developed a single paddy. How is that to be explained?--

According to my opinion, it is for the same reasons that New Guinea, Borneo, and great tracts of Sumatra remain so backward agriculturally in comparison with Java and Bali: There is no long-continued dry season and no continuous, high fertility. The original scant population was able at all times to obtain sago. A few coco trees provided nuts for the necessary fat. In addition a little fishing supplemented the diet. The above conditions satisfy the inhabitants and they do not need to exert themselves further. There is the additional point that for a primitive people in the tropics, a dry climate is apparently more healthy than a wet one. This seems to be true throughout the world. Therefore it may be that a high death rate on Halmahera prevents a rapid increase of the population. An increasing population would not have had enough food. If a larger population existed, however, it would have necessitated a more vigorous utilization of the soil to produce more food. On the young volcanic soils a more intense utilization would have been successful.--Presumably elsewhere it would not have been successful and the density of the population there has, of necessity, always remained at the relatively very low level at which it still is.

If one reads the essay by Campen already quoted above about the agriculture of Halmahera, it appears that but 50 years ago the cultivation of lowland rice was still unknown[44] and the agriculture was of a very primitive sort. In

42. C. F. H. Campen, De landbouw op Halémahéra, T. V. Nijv. en Lb. in N.I., XXIX (1884), pp. 1-17.
43. Meded. Encycl. Bur., Batavia, XIII (1917), pp. 81-86.
44. L. c., p. 2.

1917 it was recorded[45] that "Now and then paddy cultivation is tried in various places. But such tests are always a failure....they never result in the cultivation of rice." And in 1931 Hovenkamp,[46] the resident, reported: "An attempt made in 1920 to introduce the cultivation of rice in Weda resulted in a complete failure. This must be ascribed principally to the aversion of the inhabitants to regular work and to any considerable exertion."

Under such conditions we cannot expect much development of the native agriculture. It is also noteworthy that Campen in his description of kaiñgin, or upland rice culture, remarked upon how suitable the land seemed to be for various other crops: "For the cultivation of sugar cane the soil appears to be remarkably suitable. Both the higher and the lower lands are equally adapted." (p. 6).

Regarding the cultivation of tobacco by the inhabitants for their own needs he says (p. 7): "Sometimes as soon as two months after transplanting many beautiful and large leaves are plucked."

Bananas of many kinds,--and various sorts of root crops are planted out everywhere. He describes in detail the gathering of sago from the sago palms, as well as the culture of the sugar palm (Arenga pinnata), and of fruit trees.

Dammar is the most important forest product. Also of importance are rattan, nutmegs, cloves and, especially, areca nuts. Perhaps nowhere else in the Mollukkas, except on Halmahera, can such excellent areca nuts be found. These can compete even with those from Atjeh, Sumatra. Beautiful forests are found in some places, for example, beyond Wamma (Maidi).

Perhaps these estimates are still somewhat too rosy. Otherwise, if Halmahera really does possess such excellent soil, it is difficult to understand why there hasn't been more agricultural development during the last 50 years. Even though little progress has been made, perhaps there will be in the long run. In referring to the region of young volcanoes, controller Karsen[47] was of the same opinion, for he wrote, "The future of Halmahera lies not in the forests. This fertile island is by nature designed for agriculture including animal husbandry."

Now if the Government applies western science and technic to Halmahera, then the dominating natural factors will no longer apply with so much force as before. Hygienic conditions will be bettered, so that the population can increase. Through choice of crops and improved cultural methods the productivity of the soil can be increased. Therefore in the future considerable more can be expected of the young volcanic area which lies between Djailolo, Loloda, Tobelo, and Kaoe, as well as of the strip down the west coast to approximately across from Weda. Already many cocos have been planted, with the exportation of copra as the result. If the stands of sago palms in Kaoe and elsewhere are carefully and properly managed, possibly they can supply a significantly greater amount of sago. Without doubt paddies can be laid out in a number of places in this part of the island, while the land which cannot be irrigated without heavy expense can still be used successfully for many years for cassava or sweet potatoes. Because of the climate, cotton has very little chance. The region may also be too wet for peanuts. But such crops as oil palm and sisal, for example, stand a good chance of succeeding, at least as far as the nature of the soil is concerned.

And now as to the rest of the island. As has already been said above, it may be expected that there are but few localities where, if the forest be cut down, there is enough soil to begin cultivation. Possibly the best suggestion which can be given is that the forest should not be cut at all, but the natives should be satisfied with the dammar and ebony to be obtained from it. It might even be desirable to plant out in the forest a few more dammar and ebony trees, and thus insure a continuously higher production. Only the really flat land ought to

45. Med. Encycl. Bur., XIII, p. 85.

46. Vervolg Memorie v. Overgave Res. v. Ternate W. A. Hovenkamp, (April 1931), Bijl., VIII, Nota v. Toel. landschap Tidore, p. 23.

47. Mem. v. Overg. Contr. K. M. H. Karsen Betr. Onderafd. Tobelo, (1918), p. 20.

be brought under cultivation. And even most of that should be used mainly for tree crops.

CELEBES

Celebes is half again as large as Java and more than 5 times as large as the Netherlands. Hence it is difficult to state concisely its geological formation, its climate, its soil and other related generalizations. To obtain an adequate conception of this island it must be divided into natural subdivisions, which, by their names, indicate their location:

These separate parts demand individual treatment largely because of the great differences in their geological nature, in consequence of which equally great differences in the nature of the soil have developed. As will be evident from the descriptions below, these soil differences have, in turn, affected the nature and density of the population.

1. Minahasa

Soil-Forming Rocks

Without making a single serious mistake, we can lump together the soil-forming rocks of Minahasa under the one short statement that they are practically all basic volcanic. However this is not the impression one gets upon first glancing at M. Koperberg's[48] geological sketch map, since in Minahasa alone 7 colors are noted (see Fig. 130, page 315). But when examined more closely, it is of little consequence whether the parent rock consists of Miocene, Pliocene or still younger tuffs or andesites. The main point is that hypersthene andesites are apparently the most abundant, basalts less so, and hornblende andesites still less. More acid members of the series, such as trachyte occur as an apparently younger covering on a foundation of much older, basic rocks such as diorite and norite. Liparite tuffs, which do occur elsewhere in the Indies and for that matter even on Celebes, are not found in Minahasa. Obsidian however is certainly present, Mt. Kasoean (south of Menado and West from Tondano) in particular, appearing to be made up entirely of it. Thus the petrographic inventory of Minahasa seems very simple at least as long as no rock analyses are available.

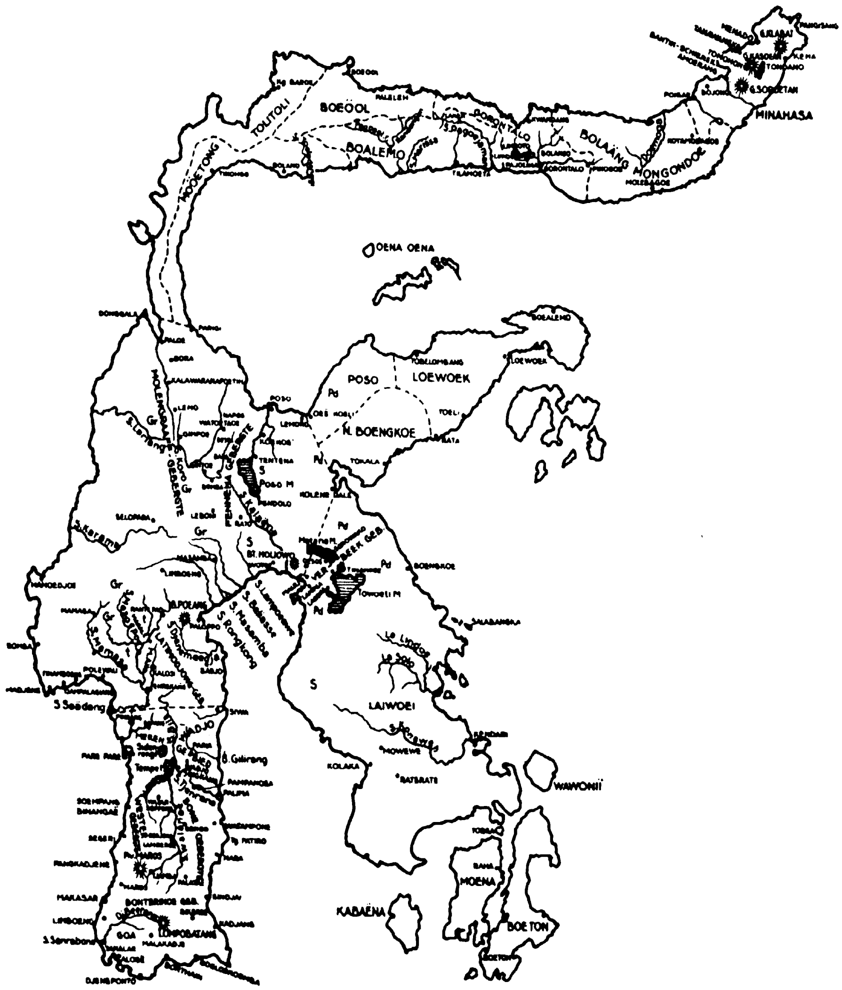
Climate

Since the equator runs exactly through the centre of that portion of the isthmus of Celebes which runs north and south, Minahasa is about only 1° north latitude. As to the temperature, there is no opportunity for those seasonal differences, such as have already been so definitely observed[49] on Timor or Southern New Guinea. For Menado the temperature averages 25.2°C in January and February, and 26.5° in August, and an annual average at 25.8°. For Tomohon, at 800 meters elevation there is not even 1°C oscillation between the averages of 20.7° in Feb. and 21.6° in May.

Here the only temperature differences of significance are those caused by the elevation, which varies from sea level to approximately 2,000 m. on Mt. Klabat, and 1,800 m. on Sopoetan. Considerable tracts of inhabited country lie between 600 and 1,000 m. elevation, where the average temperatures are about 21°C, with about 14°C for the mountain tops.

The relative humidity of the air, like the temperature, never goes to extremes. For Menado, the absolute minimum of 33% has been observed, but the average

48. M. Koperberg, Bouwst. v/d geol. v/d Resid. Menado, Jb. Mijnw. N. I., 57 (1928), Vorh. Ie en IIe Ged. Met atlas.
49. Cf: C. Braak, Het Klimaat van Ned. Indië dl. II, pp. 443-445.



Sketch Map of Celebes: After Koperberg.

Fig. 130

daily minimum is only 68%. Relative humidities of less than 25%, as a result of hot föhn winds which at times have been observed in other parts of the Indies, apparently never occur here.

The rainfall, too, is far from extreme. Seldom do completely rainless months occur. In 40 years Menado has had only 11 dry months, Masarang (900 m. elevation) has had but 5, while Kema, on the east coast, during this time has had at least 12.[50] It appears that at Amoerang, where observations were commenced much later, a markedly greater number of dry months have been recorded. In the west monsoon heavy rainfall occurs on the slopes on the northwestern coast. Menado, Tanawangko and Bojong show their highest figures for the period from December to March, although as can be seen in the following synopsis, (Table 73, page 316), the amount seldom exceeds 600 mm. per month.

As usual, the data have been borrowed from the 24th (1931) report of the Royal Magnetic and Meteorological Observatory at Batavia. In so far as has been possible, these figures have been corrected with the published figures of the rainfall data for 1929 and 1930.

The only monthly averages under 60 mm. are for stations with observations

50. Cf. C. Braak, l. c., p. 447.

Table 75

DISTRIBUTION OF RAINFALL DURING THE YEAR IN MINAHASA

Station	Number of years of observations	Elevation above sea level in m.	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Sindoran......	25	about 440	148	237	157	254	326	287	260	178	100	85	131	282	263	2560	11	0
Kema..........	41	1	109	156	166	169	167	170	152	108	76	76	102	160	157	1659	10	0
Pangisang (Marinsau)	19	about 150	137	312	277	301	213	211	142	72	48	61	94	183	229	2142	8	1
Menado.........	52	4	162	462	357	307	197	161	167	119	98	87	120	220	374	2669	10	0
Tanawangko....	23	about 300	201	437	350	306	265	275	265	178	146	182	152	308	409	3274	12	0
Tondano.......	27	640	129	190	166	162	218	208	161	94	75	100	133	212	192	1911	10	0
Masarang......	49	about 900	178	228	209	209	241	246	201	137	109	117.	170	231	228	2327	12	0
Tomohon.......	32	about 800	187	286	256	233	228	250	179	135	106	128	190	254	270	2515	12	0
Amoerang......	8	0	134	328	188	243	132	135	77	44	62	42	77	138	212	1677	7	2
Bojong........	37	about 400	187	554	507	436	338	381	359	260	227	195	248	353	497	4348	12	0
Poigar........	21	6	137	426	290	309	163	167	142	103	72	83	109	251	395	2511	10	0

for less than 20 years. It is by no means impossible that if the period of observations were doubled, those places which now have low average figures might well have them replaced by others higher than 60 mm. This would indicate that in Minahasa there are no months of which the true average would be low enough to retain them in our "arid" group.

Ways in Which Weathering Occurs and Resulting Soil Types

In a region such as Minahasa with its even climate and relatively uniform parent rocks, we cannot well expect very divergent ways of weathering nor widely varying soil types. This is perhaps the reason why in the reports relating to Minahasa we find so very few remarks about the soils, let alone descriptions of them.

Apart from insignificant exceptions, the parent material is a more or less finely broken up, intermediate to basic, andesitic to basaltic rock (**V.b.I.**), with much black cinders, sand and ash (see Fig. 131, page 317). Moreover, as a whole the rocks are rich in iron. As stated, analyses are entirely lacking. The single analysis of a rock from Minahasa is that of an obsidian, recorded by Verbeek. The results have been included in Part I (page 20) of this book.

Elsewhere than in the lake plain of Tondano and a few other similar small plains along the coast, almost always the water movement in the soil is downward (**NN.ae.**), and thus the general soil type will be an andesitic lixivium in all stages of weathering. The soil on slopes and convex places will be **V.b.I--(He to Ma).NN.ae.** **(1-4)**. In the first stage the soil will be light to dark gray and black, unweathered or just slightly weathered gravelly soil. Sometimes it will contain more sand, sometimes more porous gravel (like pumice stone). It is still embryonal[51] as a substrat for plants, hence not yet an agricultural soil.

Second stage: Juvenile, grayish brown to yellowish brown lixivium; fertile.

Third stage: Virile, a good brown lixivium; an excellent agricultural

51. The Russian School, and in consequence of it a number of other soil scientists, call soils which are still hardly weathered, "skeleton soils." This metaphor seems to me to be incorrect. This expression ought to be used for a laterite soil in the fourth or fifth stage of weathering, but fresh ash soils are "prejuvenile," thus "embryonal."

Fig. 131. Minahasa, Celebes. Mt. Aisepoet, of the Sopoetan Complex, in eruption.--Lava, black cinders and ash. (See pp. 316, 320.)

soil, moderately fertile.

Fourth stage: Senile, brownish red to red lixivium, strongly impoverished.

Fifth stage: Weathered-out laterite soil; this does not yet occur in Minahasa.

The geological literature devotes the most attention to the first stage, but volcanic slag, sand, pumice stone, etc. are not overlooked. Nor would the last stage have been overlooked, even when the material has become a laterite, since it attracts the attention of geologists as iron ore. If laterite had ever once been found in Minahasa, it would certainly have been included in the descriptions. But the intermediate weathering stage, the true "soil" stages, have been completely ignored. This is very much to be regretted. This may excuse the presentation here of only a very general and vague description of the soils of Minahasa. These descriptions are based upon a verbal description by a native of the region, which was noted down as it was given.

As soon as one ascends much above sea level in Minahasa, the soil is generally a brown to reddish brown lixivium. Only on the older Lembean mountain, to the east of Tondano lake is the ground a brighter red lixivium. This is especially the case on the outer slopes toward the south east. On the slopes of the volcano, Mt. Klabat, the soil contains much sand and scoria, which is very pervious to water and is thus but moderately well suited for vegetation, since on such a soil only a short rainless period very quickly becomes fatal. The soil is not even in the first or second stages of weathering. On the Sopoetan mountain complex (see Fig. 131) these characteristics are apparently still clearer. The latest ash-falls are still younger, and there the natural vegetation is just beginning to advance over the surface of the material. As the soil weathers more, that is, passes into the second to third stages, it becomes more beautiful and more productive. But the red Lembean soil is too senile. However between these stages lie a number of undoubtedly very fertile, first class arable soils.

In the not very extensive low land along the sea much gravelly and sandy soil is also found. Many times this exists under amphibian conditions (**V.b.I--He.NN. (am to aq.).(I-3)**), and here and there even under subaqueous conditions. By nature these soils carry quite another flora than that on the mountains, but this land has now, for the greater part, been cleared and converted into agricultural land.

Especially deserving of mention are a few flats in the mountains, of which the plains around the lake of Tondano are the foremost. There the soil to a very considerable degree--certainly as long as the lake was still larger in area than it is today--was subaqueously weathered to a soil which has developed a black, strongly humous surface soil above a dark gray, slightly humous subsoil. This material has become exposed through a lowering of the water level, and the subaquatic conditions have been changed into amphibian conditions and now the most beautiful paddies

of Minahasa occur around the lake. This is at least partly because the soil which has washed off from the surrounding mountain slopes is mixed into the existing soil.

Upon Mt. Bantik, in the west of central Minahasa, the soil is somewhat different. According to Koperberg,[52] because trachyte occurs high up on different sides of Mt. Bantik, and because its profile slopes down on all sides, it can be deduced that it must have been a point of eruption from which the glassy trachyte flowed down "in different directions....." "This earlier trachyte volcano has an older massif as a foundation which for a great part has been covered over by the mass which either flowed out or was partly blown out. In the deeper indentations (of the coast line) this older base....is exposed." From the description,[53] this foundation appears to be of diabase. There are no chemical analyses either of the trachyte, or of the diabase,--no more than there are of any of the other rocks of Minahasa. We have to be satisfied with the assumption that the trachyte soil is rich in lime, but, because of a smaller iron content, the soil has a paler yellow and perhaps even grayish color. And where it is well weathered it should be more impermeable than the iron-rich soils from andesites or basalts.

Evaluation and Utilization of the Soils

Do the inhabitants of Minahasa fully realize how good their soil really is?--This question obtrudes itself upon one who makes a comparative study of the kinds of soil of the different islands in the Netherlands Indian Archipelago.

In the introduction to his study of the volcanoes of Minahasa Kemmerling[54] says, "Minahasa is the volcanic region par excellence. Hence one must not be surprised that there is a quite dense population in this part of Celebes which, drawing a profit from the fertile soil which is easy to work, is rather well off. Great stretches of country still lie fallow: and the density of the population remains far lower than that of well-known volcanic regions of Java. Immigration to this region from the densely populated Sangihe Islands (which are also volcanic) would be the best possible move."

Then why does immigration not take place upon a much greater scale than at present? Minahasa is indeed more densely populated than many other parts of Celebes and of a number of other islands, but with only 25 residents per square km. the density is still not even 1/12th of that of Java and Madoera, where there are 315 per km.^{2}.[55] There must still be some serious obstacle to the development of this region.

In the first place, extensive, gently-sloping plains are lacking,[56] and in earlier times the volcanoes had ejected very great quantities of coarse pumice stone and slaggy bombs. At present volcanic activity has greatly lessened and the more recent eruptions have been mostly limited to streams of lava. But Kemmerling reported for Klabat and for Sopoetan "especially along the foot, fields covered with black sand and lapilli."[57] Such materials are of course not yet suitable for paddy fields since the perviousness of the soil is so great that it is impossible to hold water on them. On Java, near the Kloet and Lamongan volcanoes, lands of this sort occur but such soils are planted to various kinds of plantation crops. Where a larger proportion of the ash is in the form of find dust, paddies can be successful.

Apart from these natural hindrances there are still others which were stated as early as 1854 by officer B. B. Jansen[58] who wrote: "The nature of the terrain in

52. Jb. Mijnw. N. O. I. (1928), Verh. I, p. 138.
53. L. c., pp. 123-139.
54. G. L. L. Kemmerling, Vulkanol. Mededeel., No. 5 (1923), pp. 95-157.
55. Figures from the provisional results of the 1930 Census.
56. Cf. J. van Buuren, Versl. Irrig. Onderz. Celebes, in Jaarversl. B. O. W. (1913), V, C. Bijl. II, p. 9.
57. I.e., pp. 98, 141 and 151.
58. A. J. F. Jansen, De landbouw in de Minahasa van Menado in 1853. T. v. Ind. T. L. and V. K., X (1861), pp. 221-258; and particularly p. 232.

Photo by H. J. Lam

Fig. 132. Minahasa, Celebes. Kaiñgins with upland rice and cabo negro palms (Arenga pinnata). In the background, forest. Virile brown to brownish red lixivium soil. Yields unknown.

Minahasa, which is extraordinarily mountainous and irregular, is much more suitable for the cultivation of dry upland crops than for lowland rice (paddy) fields.

"Nevertheless, there is considerable land which may be used for paddy fields. As yet, however, not much use is made of such land, because the population in general is not accustomed to raising paddy. Also, even though the wet fields produce more rice, the farmers prefer the dry fields because they can also grow at the same time other crops which are useful. In addition, the wet fields, unless they are so situated as to be naturally wet, require the construction of ditches which many times necessitates heavier labor than the people are capable of doing. And lastly, the personnel is lacking for giving the necessary instruction in lowland rice cultivation and for providing the necessary supervision. At the same time the extraordinary fertility of these soils makes this region preeminently suited to the cultivation of rice."

It is now 80 years later than when this account was rendered. Much has been done, but certainly there is still very much more to be done in the way of irrigation. At that time rice was exported; now, as a consequence of economic causes, much rice is imported. The nature of the soil, however, is such that it is very probable that rice imports should not be necessary. The upland dry rice fields (kaiñgins) are still scattered everywhere and are the principal type of cultivation (see Fig. 132 above).

Meanwhile Minahasa is developing along other lines. The world demand for copra has induced the inhabitants of the coastal regions to plant countless coconuts. The coco palms grow excellently on the pervious, brown and reddish brown volcanic, lixivium soils. For the time being there is still plenty of land. And so although the inhabitants realized that a definite area, when used for lowland rice produces more than when used for a coconut grove, yet they have planted coconuts everywhere, since there was no shortage of arable land to force the people into more intensive agriculture.

Paddy fields have been developed

only on swampy soils, such as those around the Tondano lake and on other similar lands, where, on subaqueous or amphibianly formed black soil the coconuts grew poorly or not at all. The fields have proved to be very good ones.

It is a great regret of mine that in the literature I have never been able to find figures on the yields of lowland rice for Minahasa. This is also true for upland rice fields, maize, and coconuts. If such figures were only available in adequate numbers, and were reliable, it would probably be possible to draw important conclusions for the future. If one reads over the above already-quoted report of Van Buuren one finds that even today (1931) not a single figure of production can be given--in spite of the many irrigation possibilities of Minahasa. For example how many people should be able to make a living in the most southerly part of Minahasa? In the river valley of the Poigar River and of the Ranojapo River[59] on good, irrigable, volcanic soils?--And there are also other localities which from an agricultural standpoint are without doubt full of promise. Yet in 1932[60] it was stated that "As a whole the irrigable areas are still not half planted" so that even yet quite a good deal of time will have to pass before there will be a definite need for additional irrigable lands.

At present the plains around lake Tondano are the best of the lot. It would be very desirable to be able to accurately compare the productivity of these plains with those of other mountain plains of the Netherlands Indies, which likewise originally were lake bottoms. Examples of such plains are those of Bandoeng, Korintji, and Taroetoeng.

Besides dry rice and paddy a number of other crops are raised in Minahasa. Cocos have already been mentioned. They are found far inland. How many nuts, however, a tree produces, seems to be unknown. In a recent paper dealing with "copra in Minahasa"[61] there is a separate chapter about the "production of the native groves, but without a single figure.

The cultivation of coffee has already well justified itself. It is noteworthy that as long ago as 1853 Jansen[62] remarked that "Minahasa possesses much good land suitable for coffee, of which that lying around lake Tondano is the best, and excels those lands in the districts of Rembokan and Kakas"--Rembokan and Kakas are near the lake. There are no rainfall observations aside from those at Tondano and these are quite low figures (see Table 73, p. 316). Should not the relative drought of the surroundings of Tondano lake be considered in the determination as to what the best coffee districts are?--Also further remarks by Jansen[63] give the impression of accurate observation. He says "The mountain flats close to the lake, with an elevation of from 2,000 to 3,000 feet, appear preeminently suited to coffee. But the farther one goes from there, however," (Jansen presumably means in a southwestly direction, up on Noöngan and still farther) "the more the land decreases in quality, and in the regions about Sepoetang (Sopoetan) volcano, an important area is covered with volcanic ash" (sand and lapilli?), so that it is infertile, and at least at present, unsuited for coffee cultivation." As weathering in these localities proceeds, however, coffee cultivation will be successful on the higher slopes, while on the lower edge it will be less and less satisfactory. The slightly weathered soils are greatly benefited by a green manuring. Van Aken, in referring to Noöngan writes as follows.[64] "As a rule however, the harvests are below normal, since the very sandy soils possess too little humus. The interplanting of Crotalaria anagyroides between maize has indicated that greater yields may be obtained in this way."

There was never very much cultivation of cacao and what there was has now been given up entirely. The climate in Minahasa is also apparently less suitable for this crop. Nutmegs grow better, but

59. Compare: Verslag Van Buuren, l. c., p. 12.
60. Mem v. Overg. Res. Van Aken, Mei 1932, p. 141.
61. Econ. Weekbl. v. N. I., I, No. 16 (1932), p. 630, sub "Handel."
62. L. c., pp. 221 and 222.
63. L. c., pp. 221 and 222.
64. Mem. v. Overg. Res. A. Ph. van Aken, Mei 1932, p. 160.

there is not enough sale for them. The same is especially true of cloves. In recent years the cultivation of cloves has been considerably extended, especially upon the quite reddish, southeastern slopes of the Lembean mountains.

Tobacco is grown only for home use, though this crop grows very well in numerous places.[65] One is inclined to suppose that these places have relatively juvenile, light, sandy, ash-loam soil, which holds water well. Only investigation on the spot can reveal whether this presumption is correct. Neither is it known whether very immature or rather mature soils are unsuitable for tobacco growing. One might suppose that Minahasa, with conditions in other respects favorable, could be expected to become an exporter of tobacco, as is considered possible for the volcanic regions of Halmahera.

There also appear to be opportunities for the growing of abacá (Manila hemp, Musa textilis) in these lands. Jansen[66] has already mentioned it, saying "it is asserted that the product of the abaca plantings along the beach is better than that of those grown on higher lands and in the localities with a cooler climate."

Taking all the above mentioned facts together we must certainly count Minahasa, at least as to the soil, as one of the good and most promising portions of the Archipelago. Most promising, in that the basic volcanic parent material of the soils will continue to develop new fertility through soil weathering and as a result of the application of green manures, for which this land is particularly adapted. If we accept the theory that the population will increase through mutual interaction and, as a result of the agricultural enlightenment, agricultural technology continues to progress, then the prediction that Minahasa will offer satisfactory conditions for a considerably greater population than that of today, is certainly not exaggerated.

THE NORTHERN NECK OF CELEBES

To more closely fix the region, known as the "Northern Neck," let us in the first place state the localities which make up this region:

a. Bolaäng Mongondoe
b. Gorontalo
c. Boalemo
d. Boeöol
e. Tolitoli
f. The small northern portion of Parigi (with Moöetong)
g. The small northern portion of Donggala.

A single mountain range runs through all these localities. For the most part it is a single ridge, though sometimes bent and broken, and sometimes paralleled by one or more accessory ridges. Upon closer analysis many different elements of the landscape can be distinguished, just as in the Barisan mountains of Sumatra. In general, the region can be likened to the vertebral column in the neck of a bird. Seen from an airplane at a high altitude the landscape from one end to the other is all the same: a very rough mountainous region, in which there are only a few bits of flat land. Except for larger or smaller cleared portions of these flats the whole landscape is covered by one continuous virgin forest.

Soil-Forming Rocks

Since gold has been found at a number of places in the Neck, the geology of these localities has been fairly accurately studied in certain local areas. That there has been no general study of the geology is demonstrated very clearly by Koperberg's maps[67] on which geological and petrographical findings are given only along the rivers and a few roads.

The inventory of the rocks of

65. Jansen (l. c., p. 250) wrote (in 1854!) "The soil in Minahasa appears to be especially adapted for tobacco....and the quality of the product is considered to excel that of Java tobacco." (But this was written 80 years ago!)

66. Jansen, l. c., p. 244.

67. M. Koperberg, Bouwst. Geol. Resid. Menado, Jb. Mijnw. N. O. I (1928), Verh. I and II, Atlas, Platen II b-d.

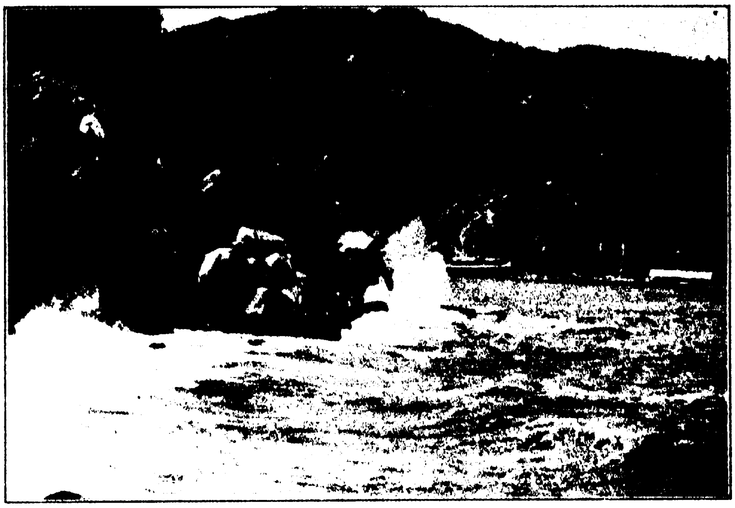


Photo by P. K. Heringa

Fig. 133. Celebes. Entrance to the chasm-like harbor of Gorontalo.-- Granite boulders in the surf. In the distance a steep granitic slope kaiñgined off. Poor reforestation on the eroded slopes. (See p. 329.)

Minahasa was as simple as that of the further northern Neck of the Celebes is complicated. Here in the Neck are rocks of many different ages and differing widely petrographically.[68] Beginning with the oldest, there are crystalline schists, as well as gneisses and mica schists, chlorite schists, hornblende-actinolite schists, phyllitic slates, greywackes, quartzites and crystalline limestones. There follow all kinds of limestones and marls, sandstones and other sedimentary rocks of very variable age. And then igneous rocks, of which granites, diorite, gabbro diabase, and "shell stones" (?) are, perhaps, the chief ones. In short--the variety is of the greatest, but it is at present still impossible to state the extent and relative importance of each rock, not even if we limit ourselves to the rocks which might be considered definitely soil-forming. At most, we may perhaps make the following remarks:

In the east, in Bolaäng Mongondoe, there still occur a few young volcanic regions, but toward the west the younger vulcanism is presumably absent. There are large granite regions, such as near and especially back of Gorontalo (see Fig. 133) and along the southern coast of the broader part of the neck running east and west. Also gneiss, dacite, and chlorite schists occur over quite large areas. More toward the center from north to south there are quite a few mountains of diabase.

We should add that presumably along the outer curve of the neck more sedimentary rocks, such as limestone, marls, and sandstones, occur than along the inner curve.

Climate

The equatorial climate of the Northern Neck of Celebes offers little variation in temperature. According to Braak[69] the strength of the monsoon winds decreases from the east toward the west, where their place is taken by the periodical land and sea breezes which become of predominating significance. As for the rainfall, if we consider the averages of many years there appears to be a quite regular distribution of the rain throughout the entire year. But individual years

68. Cf.: H. A. Brouwer, Geol. Overz. Oostel. Ged. O. I. Arch., Jb. Mijnw. N. O. I (1917), Verh. II, pp. 145-447, and especially pp. 173-174, 221, 233, 246-248, 271, 296, 308-309, 315, 405-407 where there are also found additional references. M. Koperberg, l. c., I, pp. 237-297 and II, pp. 1-255.
69. C. Braak, Het klimaat v. Ned.-Indië, Verh. Kon. Magn. en Meteor. Obs., No. 8, Dl II, p. 420.

show considerable divergencies and all sorts of irregularities.

Where the sea winds must travel upwards against mountain ridges, the monthly averages indicate moderate "moistness," ranging between 100 and 300 mm. as at Bwool. If the influence of the monsoon comes from the direction of the sea, as at Kwandang, during the west monsoon, and at Molobagoe during the east monsoon, the figures become somewhat higher. If the influence comes from the opposite direction, then the rainfall is somewhat lower, as at Tinombo in the west monsoon.

If, however, a lowland plain lies between mountain ridges, then, from the nature of the case, the rainfall is always less. This is clearly seen in the plain of Limboto behind Gorontalo: there no monthly average is above 150 mm. Moreover, the east monsoon is intercepted by the mountains southeast of the plain on the coast, hence during this season there are a couple of dry months and the annual total rainfall amounts to but about 1200 mm.

The following table (Table 74) has been compiled, as have been a number of previous tables, from the data of the Meteorological Observatory at Batavia. This table shows a number of interesting things.

Rainfall figures are still not available for the Doemoga plain in Bolaäng Mongondou and the Pagoejaman plain in Boalemo; but by analogy it may be accepted that for the former the total will remain under 2 m., and for the latter the total may even be under 1 1/2 m., while the monthly averages will not exceed 200 and 150 mm. respectively.

Principal Ways in Which Weathering Takes Place and the Resulting Soil Types

Irrespective of whatever the nature of the parent rock may be, mountain slopes running down toward the northern coast or toward the southern coast must be exposed to a continuous leaching. A sufficiently dry monsoon is always lacking. Brown, brownish yellow and brownish red lixivia will be darker in tint as the parent rock is richer in iron (for example, diabase or

Table 74

DISTRIBUTION OF THE RAINFALL THROUGHOUT THE YEAR, IN THE NORTHERN NECK OF CELEBES[1]

Place	Number of years of observations	Elevation above sea level in m.	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Ponosakan	12	590	153	270	227	284	362	339	182	173	89	117	169	365	330	2910	11	0
Kotamobagoe	20	610	150	165	158	178	217	247	173	121	84	116	151	214	172	1996	11	0
Molobagoe	14	at sea level	98	152	164	155	169	325	485	372	331	308	101	72	156	2790	11	0
Kwandang	49	"	124	311	258	204	169	199	170	115	101	101	140	217	256	2241	12	0
Paleleh	29	"	153	317	354	286	184	197	194	162	136	130	139	251	283	2633	12	0
Bwool	13	"	117	246	185	189	155	155	182	133	120	115	111	156	179	1926	12	0
Tolitoli	49	"	141	227	186	145	132	213	243	210	194	170	176	146	205	2247	12	0
Gorontalo	49	"	106	109	120	112	126	108	115	89	72	45	64	107	134	1201	8	1
Boidoe	10	30	116	119	141	146	109	125	119	74	52	55	72	110	135	1257	8	2
Limboto	49	8	105	142	110	126	143	139	106	75	57	47	70	138	152	1305	8	2
Boelila	18	13	112	117	133	107	124	137	89	64	43	36	58	107	117	1132	7	3
Pajoenga	10	10	81	89	105	134	150	117	120	76	39	38	45	142	142	1198	7	3
Tilamoeta	15	at sea level	117	164	138	182	168	161	196	200	105	69	60	104	128	1675	10	0
Tinombo	14	"	103	59	63	90	167	183	152	140	110	118	65	77	66	1291	6	1

1. J. Boerema, Regenv. in N. I., Verh. 24 (1931), p. 204; supplemented, in so far as possible, with the data for 1929 and 1930. Further figures have not yet been published.

gabbro). Since the mountainous land is very rough, it is ill-adapted to extensive settlement. Thus it is thinly populated and still covered with virgin tropical forest. The soil under such a forest cannot dry out thoroughly. Furthermore the iron oxides do not lose their water but remain a yellow color.

If, therefore, bright red or even purplish red soil colors are found in these humid districts, it may be considered a priori very improbable that such soil types could have been developed from any igneous rock under the weathering conditions prevailing at the present time. Except for certain local effects of a pneumatolitic nature, which also seem to give rise to such tints, the cause of the purplish red color of the soil referred to must be sought in the parent material, which may be for example, sedimentary rocks originating from deep sea sediments. Even if the sediments were, perhaps, not originally deposited in the deep sea but might have been coastal or even terrestrial sediments, or for the most part may not have been sediments at all but had been formed residually as brown or red lixivium, even so, very probably they had afterwards passed through the deep sea stage, during which time the iron hydroxides could have been split into water-free iron oxide (hematite) and water. However, any further discussion of the genesis of such rocks must be left to geology.

If diabase and other basic rocks weather to clearly brownish yellow lixivia, the granites of many kinds and the related rocks give rise to soils which are paler in color as the iron content is lower. The intermediate, young volcanic rocks from Bolaäng Mongondou, lying to the east, also weather into brown to yellow lixivia. Where, however, all this material is eroded directly into the river valleys and is deposited in smaller to wider plains, opportunity is afforded for amphibian or subaqueous bleaching and thus for the development of very light colored soils. The recently deposited colluvium and alluvium remain a yellow to beige color, although the subsoils of the soil profiles in the plains tend to be more of a grayish white. If the parent rocks contain much mica, then the soil glistens because of the great numbers of little mica flakes which resist weathering for a long time. The small plain of Bolano is a notable example of this.

Summarizing, we can say that where the predominating parent rocks are basic, rich in iron and lime, the soil inclines toward the brown to red lixivium type which on the slopes is not further developed than the virile stage. In this land of very rough topography the soil cannot weather as far as a really senile stage, since the soil erodes before that stage has been reached. Thus the soil is continually rejuvenated. In the east, in Bolaäng Mongondou, on the porous tuffs there is more possibility of soils remaining in place long enough to weather to the senile stage.

Where acid parent rocks, such as dacite, granite, and mica schists predominate, pale brownish yellow lixivia must develop. Because of the humus content the profiles of these soils must have a surface soil more erosive than the subsoil. Here surface erosion is certainly more obvious than in tuff regions, and a quite impervious subsoil limits the tropical rain forest to only very moderate luxuriousness.

The quite large plain of Limboto is surrounded by mountains consisting of considerable granite. It is possible that on the alluvia which has accumulated in this plain, with a climate which for these regions is very certainly dry, in the course of a long time there may develop a gray to black soil which might be called "black earth." That is, a heavy, cracking, strongly plastic black clay **[Gr-Wa.nn.ae.3] al-He.nvv.am.(2-3)**. As yet the soil here is not as far along as that. Nevertheless there are indications that the development is in that direction. If lime-rich alluvium washes down from the mountains onto the plain, then the pH will be increased.[70] This will promote the formation of black earth, as on the northern slopes of the Padang Hoeloeloe. But whether or not black soils are present is more a question as to whether or not the dry monsoon is long and intense enough.[71]

In so far as data are available,

70. Compare: C. H. van Harreveld-Lako and O. Arrhenius, Grondond Buit. Bez., Meded. Pr. Java, Suiker-Ind. (1927), No. 18, Archief S. I. Ned.-Ind., p. 776.

71. Compare: The same, pp. 783-791 and Koperberg, l. c., Kaart ol. 3 (Plate IIc).

the impression is that the plain along the Pagoejaman river, or at least the greater part of it, is now being covered over by weathering material from granite. That being the case, the surface soil must be predominantly a pale yellow fine sandy loam or gravel. But that does not deny the fact that heavier loams and also clay may occur in the subsoil. The plain is known to have been a lake, and these layers have been bleached by more or less amphibian or even aquatic conditions. As far as is known, no rainfall figures are available for stations on this plain. Presumably they would be like those of the Limboto plain, although perhaps somewhat higher. But that the rainfall cannot be high, and consequently the leaching not intensive, seems to be proved by the existence of spots where "small clay hills with shells" project above the general surface of the plain. Van Harreveld-Lako and Arrhenius[72] consider these soils to be "old diluvial lake soils"; in which the lime of these shells still remains well preserved. The pH of the surrounding heavy gray clay does not exceed 7, and on the Pagoejaman plain the pH almost never falls below 6.4. According to what was said above, pages 183-186, the mechanical analyses given by the above-mentioned authors (L. c., p. 791) exhibit curves which make it very probable that practically all of the samples must be considered as belonging to secondary, allochthonous soil types. These types include loamy sand, sandy loam, and heavy loam.

Evaluation and Utilization of the Soils

There is a singular discordance between the evaluation of the soil in this portion of North Celebes and its utilization. From the European point of view, such as is expressed in a number of "Notes of Giving Over Charge" by various civil officials, the evaluation is practically always favorable, particularly with relation to the soils on the plains. With regard to the mountain ridges there is an almost equally unanimous opinion that it is best that these soils be kept under the forest which is still practically unbroken. From the local point of view the low evaluation is expressed only in deeds, not in words, being indicated by only a very moderate development of agriculture on the plains. In addition one sees only a few attempts at kaiñgin cultivation on the mountain slopes. As a consequence the entire surface of the northern Neck of Celebes is but extremely thinly populated.

While it is repeatedly the case that a relatively dense population lives on poor and infertile soils, the reverse is also true. A soil which is rather productive, and here and there even "very fruitful" still remains thinly populated. It is possible that the soil is not as good as the high rating would seem to indicate; but it is also possible that other factors such as diseases, wars, etc., which have nothing to do with the soil, have prevented an agricultural population from becoming dense.

In order that we may know more about this point soil investigations should be carried out in the field, supplemented by soil research in the laboratory. There has not yet been much done in this direction and for that matter little will be needed in the near future, not even with reference to the plains, which here, as elsewhere, are evidently the most important part of the country. The little information which the literature provides may be found in the above referred-to bulletin by C. H. van Harreveld-Lako and O. Arrhenius of the Experiment Station of the Java Sugar Industry, Pasoeroean. There these authors give a number of mechanical analyses. Unfortunately no mineralogical characterization of the different fractions is given. This paper also gives quantities of P soluble in HCl and in citric acid, pH values, carbonate content, and amount of gravel.

Very meagre information is available relative to the utilization of certain of the most important of the plains, namely those of Gorontalo and Limboto. From the results of the analysis it appears that the soil of this plain often has an alkaline reaction, and here and there it contains more or less marine shells and coral remains. According to the opinion of

72. L. c., pp. 784-786.

geologists this plain is to be conceived of as a former bay of the sea, which was later elevated and is as yet but little covered over by recent alluvium. According to Van Harreveld-Lako and Arrhenius[73] in general the phosphorus content is high, especially in the north and the east, namely 0.052 - 0.099% HCl soluble P_2O_5 and 0.02 - 0.056% citric acid soluble. The more grayish black spots in the southwest contain less namely 0.008 - 0.039% HCl soluble and 0.001 - 0.015% citric acid soluble P_2O_5. As far as these figures indicate we can certainly expect better returns from the irrigation works completed in 1926-1931 on the Bolango river in the northeastern part of the plain.

In connection with this irrigation an interesting observation can be made. Almost all irrigation works in Java are laid out on immature, volcanic soils, with irrigation water coming from volcanic regions. Here, however, there is a (presumably) purely granitic hinterland, which provides the water, and a terrain which, at least in its surface soil, is also made up of weathering products largely derived from granite. Here we shall have in the future an opportunity to see whether or not irrigation in such a granitic region can compare in continuous fertility and yields with the irrigation of young volcanic regions. But then one must be able to control both the soil and the irrigation water. Hasn't it just been said above that before the land was irrigated high amounts of P had been found in this soil? And now it is a question whether or not P is also to be found in the irrigation water, or whether the soil, perhaps in connection with its previous marine history, had accumulated a considerable supply of phosphorus. Moreover, although P is quite important, it is not everything! For example, how does the granitic alluvium behave as paddy land in other respects--physically, biologically, and otherwise? There is every reason to consider this question from all angles, particularly because granite predominates on other islands of the Archipelago. We immediately think of Borneo, New Guinea, Billiton, Bangka, and the Lingga Archipelago. Down to the present time the opinion has always prevailed that little or nothing was to be expected from paddy cultivation on lands of this sort. But considering the results thus far obtained in the Bolango irrigation district,[74] this opinion begins to be shaken, and perhaps, at least under some circumstances, this opinion should no longer be held. The consequences are so important and apply to so many important regions that serious comparative research into this question is indeed very necessary. This is particularly true with regard to still other, recently projected irrigation schemes where similar irrigation water would be used upon the same sort of soils.

A clue is given by H. H. Morison.[75] During the years before the new irrigation project, the yield from the Bolango irrigation district was small. Then as water became regularly available from the additional works, the yields rose proportionately, of course principally because of the extension of the area planted.

Old conditions	1926	--	625.32	metric	tons	paddy.
	1927	--	728.01	"	"	"
	1928	--	1,773.61	"	"	"
Beginning of the new irrigation	1929	about	3,088.	"	"	"
	1930	"	9,017	"	"	"

Of the total area of 2,931 Ha. in the irrigation year 1929/1930 there were already 2,420 Ha. cultivated. In 1930/1931 this increased to 2,743 Ha. According to harvesting test cuts in 1930 2,120 Ha. gave an average yield of 3088 **Kg.** wet or 2460 Kg. dry paddy, an excellent figure. This compares favorably with figures obtained elsewhere. But 255 Ha. (thus more than 10%) were attacked by the mentek disease and gave a yield of only a half of that of the healthy fields." This is a warning to watch the soil closely.

According to A. O. Frohwein[76] the harvest in 1932 had already risen to about

73. L. c., p. 776.
74. See: Jaarversl. Afd. Landb. Buitenzorg (1929), p. 312.
75. Mem. v. Overg. Contr. Gorontalo (Febr. '31), p. 50.
76. Mem. v. Overg. Gezagh. v. Gorontalo, (Apr. '33), p. 28.

11,640 metric tons of paddy, and for 1933 the estimate was at least 12,350 tons, which led him to state that: "This year the yield of paddy is gratifying."--"The new groups of rice fields extend day by day. The working of the land, earlier so inadequate, is becoming more intensive and appropriate, thanks to the instruction of Agricultural Extension Service."

If we contrast this with the state of affairs which prevailed no longer ago than 1923[77] when the average yield was only 12.6 quintals per ha. we see that the progress has been truly enormous. This is to be ascribed both to the irrigation, which gave certainty to the harvest, and to better cultivation, as the result of good advice.

The Doemoga plain lies more to the east. As it is surrounded by mountains of very divergent geological nature and of varied petrographic constitution, its soils are very heterogeneous. In one place the purplish red color of the soil and the sand present in it, originating from purplish shales, is apparent. In another place the color is a pale yellow with more or less fine sand coming from rocks containing quartz with a moderate content of the darker minerals. The chemical analyses by Van Harreveld-Lako and Arrhenius (l. c., p. 794) indicate that while 6 samples contained much phosphorus namely 0.44-0.124% HCl soluble P_2O_5 and 0.014-0.075% citric acid soluble, 24 other samples contained but moderate to small quantities of P_2O_5, namely 0.009-0.060% HCl soluble and 0.001-0.009% citric acid soluble. Thus the soil is apparently poorer in phosphorus than that in the neighborhood of Gorontalo, so that it will be quite important to know the composition of the water and silt of the Doemoga river before the commencement of the construction of an irrigation system using this water. However, for the time being, there is no talk of this, since perhaps at most five persons per km.^{2}, are living here. This does not indicate a very fertile soil nor is it an attraction for new settlements. Besides, as far as one can conclude from the few mechanical analyses, the soils are quite heavy.

Toward the west is the Pagoejaman valley. It is joined to the plain of Gorontalo and Limboto by a low saddle, only 160 m. above sea level. Since most of the mountains which surround this plain are of granite, the plain is built up mostly from weathering materials from rock of that kind. However, the material accumulated in a depression which was apparently originally a lake, at least in the lowest part. The Pagoejaman river cut down its bed in the pass toward the south leaving the plain dry. The result is that there are two kinds of soil formation in the alluvium. In the lowest parts is young subaerial or, at most, amphibiously weathered alluvium upon a substratum of alluvium deposited in the lake. This is soil material which, without doubt, had been formed under subaqueous weathering conditions. There is only subaerial alluvium in the higher parts of the valley, which at the time of the existence of the lake remained dry.

Here and there what has been supposed to be the old lake soil is exposed in the form of small mounds of heavy blackish gray clay, only a meter high and a few meters in diameter, speckled with weathered grains of feldspar and residues of shells. On these mounds bleached shells are always to be found, apparently exposed by the rain, while elsewhere in the alluvial plain they are almost never to be seen.[78] But it is as yet not certain whether these "mounds" are relics of the lake alluvium, or whether they are projecting points of the underlying granitic rocks.

The quantities of phosphorus recorded are very divergent: from 0.001 to 0.105% HCl-soluble P_2O_5 and from 0.004 to 0.058% citric acid-soluble. The soils richest in P appear to be scattered. Yet it seems that in the upper stream valley, thus higher than Lakea, there are almost no soils poor in phosphorus. This ought to be an indication that the water of the Pagoejaman River is relatively rich in this element. In conformity with this, various soils close to the river and in the lowest places on the plain, likewise show high P figures. But to say more about this would be too speculative.

A few smaller, more westerly-lying

77. Mem. v. Overg. Ass. Res. v. Gorontalo J. E. Edie (Juli '23), p. 20.

78. Van Harreveld-Lako and Arrhenius, l. c., p. 785.

plains are also mentioned by Van Harreveld-Lako and Arrhenius, namely the Randangan plain, along the Randangan and the Marissa Rivers, and the Bolano plain, along the Toeladenggi and the Lamboenoe Rivers. From what has been stated as to the P and pH figures and mechanical analyses of the soils of these plains, the impression is that they are light loams, with astonishingly high amounts of P.

Perhaps it is because during the rainy season practically all the lands except a few higher spots and strips along the rivers are continuously under water that these regions, although they seem to have a good, fertile soil, are so thinly populated. Yet one cannot help wondering whether this is, indeed, the real reason. Because certainly elsewhere in the Archipelago this condition also prevails. For example, in Palembang, Sumatra, between the Ogan and the Komering rivers and yet in the "lebaks" there is a quite dense agricultural population. More definite data about this condition are most certainly desired. Perhaps there is some major obstacle of dominating influence which can be removed by relatively simple or modest methods.

In the report by Van Buuren,[79] besides minute and valuable descriptions of the terrain of the above-discussed as well as still other irrigable plains, all sorts of significant information for the irrigation engineer may be found.[80] But Van Buuren's investigation was made nearly 20 years previously. There is little or nothing in the report about the soil, and just as little about the nature of the water and the silt of the rivers which will eventually be used for irrigation.

* * * * *

Now just a few words about the crops on the uplands, and about the forest. Maize is the most important food crop and coconuts the leading money crop. In many places in this part of Celebes both crops are in their element. There is much light, sandy and yet fertile loam, with adequate soil moisture.

Now that the price of copra has fallen so much, more attention is being given to the raising of kapok.[81] Also, in some places, cloves are cultivated.[82] Coffee and cacao, once relatively important in these regions, have just about completely disappeared. It is said this is because cocos require less work and give more income. Whether diseases or soil conditions also play a role, remains an open question, since in the literature there is nothing to be found about these points. Morison[83] considered that "on the plateau of Pinogoe, about 300 meters above sea level, very good land exists for the cultivation of coffee, as is proven by the couple of thousand coffee bushes existing there." He called this locality "indeed, the most fertile part of the province of Gorontalo."

The cultivation of cassava, (Manihot utilissima), sweet potatoes, bananas, and other fruit trees is also practiced. Therefore the natural requirements for an increasing well-being of the people are present in northern Celebes.

The forests, in the neighborhood of the denser populated localities, are certainly being destroyed at an alarming rate through injudicious kaingining (see Fig. 133). But fortunately farther back in the mountains much forest still remains untouched. Whenever the market is favorable, considerable quantities of copal and rattan are obtained from these forests. But here as elsewhere, much rattan has been exterminated.

In connection with the deforestation, particularly in the country around Gorontalo two points deserve separate mention:

In the first place Morison has noted,[84] as well as others, the erosion

79. J. van Buuren, Versl. nopens een ingest. irrigatie-onderz. in Celebes, Versl. B. O. W., V (1913). C. Bijl. II (1916).
80. L. c., pp. 12-17.
81. Cf. Mem. v. Overg. Contr. Gorontalo, H. H. Morison (Febr. 1931), p. 47.
82. See: Mem. v. Overg. Res. Menado J. Ph. van Aken (Mei 1932), p. 159.
83. L. c., pp. 3-4.
84. L. c., p. 24.

of the mountain slopes as the results of the deforestation. Although cogon (Imperata spp.) has an extensive root system, it is not capable of holding the soil in place. In many places the mountain soils are already so seriously eroded that the rocks are exposed at the surface. The sanding up of the mouths of the rivers has also been very much hastened by the extensive deforestation." Van Aken[85] supports this conclusion by describing a special case: "the consequences of this reckless destruction of the forest are especially evident on the northern slopes of the Bone mountains. The creeks which flow down to the north wash off great quantities of coarse sand, which has been bad for the coconut groves in the Bone valley and for the harbor of Gorontalo, into which the Bone river empties. And this is the main cause of the progressive filling up of this harbor with sand. Thus here is a case analogous to those on the south western coast of British India.[86] The description of the complete ruination of some earlier important harbors and roadsteads justifies the strongest fears that unless the devastation of the forests is checked and all possible efforts directed toward reforestation, the harbor of Gorontalo will be completely ruined.[87]

Secondly, Frohwein writes:[88] "Recently there has been concern over the fact that in some places the cattle pastures hardly deserve this name. Around Limbotto Lake, in the Telaga sub-district, during a portion of the year the pastures are continuously submerged, so that during last year a hundred cows died because of lack of food. On the large Kaliba pastures a kind of plant which the cattle do not enjoy has become dominant. This plant grows luxuriously and suppresses everything else,--all the useful pasture grasses for the cattle, and other kinds of plants."

"This is a notable case: the epidemic invasion by one sort of plant, apparently still without name, hence previously unknown in this locality. If it has been imported, then it is important to quickly look into its requirements of soil and climate, to learn whether or not because of altered conditions in the soil, (and/or climate) a previously unpretentious and unnoticed plant has been enabled to spread everywhere. In the Netherlands something of this sort has occurred, namely the terrible spreading of sorrel on many run-out pastures. That also is a soil question, to be remedied by appropriate fertilization.

* * * * *

With reference to the western part of the northern neck of the Celebes there are still a few particulars which may be mentioned. In a military memoir relating to the Parigi[89] subdivision, it is recorded that in the neighborhood of Tinombo tobacco and onions were cultivated, the latter even in such amounts that considerable quantities were exported from there to Gorontalo and Poso. Hence the soil in this region must indeed by of good quality. The relatively dry climate (not even 1,300 mm. rainfall per year) will also contribute to this. There is sufficient rain to weather the soil quite well, but not enough to seriously leach out the plant nutrients.

It is also recorded that sugar is produced in various places along the eastern coast of this part of the Celebes. A glance at the map shows a strikingly large number of villages there. This is because of the good yield of cocos in this stretch along the Tomini gulf, presumably likewise to be ascribed to the favorable influence on the soil of the relatively dry climate. The opposite coast, more exposed to the west monsoon, is clearly less densely populated and is apparently less fertile.

85. See for example also: Mem. v. Overg. Res. Manado: J. Ph. van Aken (Mei 1932), p. 170.

86. See Nature, 119 (1927), No. 2984, p. 38.

87. Compare: J. B. H. Bruinier, De Bosschen v/d Minahasa en Bosch-reserveering, Publ. No. I, Noord-Celebes-Inst. (1924).

88. L. c., p. 29.

89. Neither signed nor dated, but internal evidence indicates it was written later than 1929.

3. Central Celebes

In order to avoid any misunderstanding as to what is meant by this term, let us draw on the map an imaginary broken line through the following places: Donggala, Parigi, Lemoro (east from Poso), Kolonodale, Malili, Mamasa, Madjene and up along the west coast to Donggala again. The region roughly enclosed by this line is the one which we will discuss under this heading. In various respects this large region is so heterogeneous that no further subdivision, not even a rough one, can well be made. Hence, as an introduction to the region we will proceed at once to a consideration of the

Soil-Forming Rocks

The diversity of the rocks is still greater than in the northern peninsula, and the geological structure of the very rough and rugged mountainous regions is far from simple. Least of all, to repeat again what has been said so often, it is not our purpose to go into the real geology itself. The reader interested in that is referred to the geological literature relating to this region.[90] Also it must be definitely stated that our geological and petrographic knowledge of Central Celebes has been obtained practically entirely since 1900 and is still so fragmentary that Brouwer did not wish to show on his sketch map much more than that which he and his companions themselves definitely observed. Relating to the soil, Abendanon is the only one who has recorded observations, and while his notes are only incidental, they are, nevertheless valuable. That Rutten in his critical discussion summarizing purely geological data did not refer to the soils is to be expected. While Brouwer, and for that matter most of the field geologists, apparently tried to carefully exclude from their publications all that concerns the soil. So that, aside from the work of Abendanon mentioned above, we are forced to fall back upon the communications of administrative officers for data regarding the soils, since agricultural officers are not yet employed in the region in question. Thus the reader now knows in advance that regarding the soils of Central Celebes but little definite information is to be expected.

* * * * *

Referring to the most recent publication, that by Brouwer, we learn that east and west from the central Poso depression are extensive tracts of crystalline schists, which, in themselves, are quite variable. For example east from the central line, biotite is lacking in the schists, while in the region to the west of this line biotite is a well distributed mineral in the schists In the eastern region with these schists much mica limestone and limestone phyllites occur. In the western region, on the contrary, mica schists occur over great areas. Also white quartzites and locally muscovite gneiss occur, but almost no carbonate-rich rocks are present. As it concerns the formation of soils, this is an important difference, as will be mentioned farther on.

Westerly from the schist regions there is the extensive zone in which are situated the tracts with much intrusive granite. Besides granites and granodiorites one comes across gneisses and many other kinds of rocks, even ultrabasic ones at a few points. What is known about them, even today, especially as to their distribution and extent over the surface, is still too inadequate to warrant more than mere mention here.

Easterly from the schist regions one first comes upon the Pompangeo mountains, which for a great part consist of less metamorphosed clay shales, greywackes, sandstones, and limestones; rocks which one also finds farther eastward, especially toward the southeast before reaching the great expanses of serpentine and peridodite.

90. It may suffice here to give a very limited selection: E. C. Abendanon, Geolog. en geograph. doorkruisingen v. Midden-Celebes (Leiden, 1915-1918), Bd. I-IV, plus atlas; L. M. R. Rutten, Voordr. geologie Ned. O.-Indië (Groningen, Den Haag, 1927); H. A. Brouwer, Geol. onderz. o/h eil. Celebes, Verh. Geol. Mijnb. Gen., Geol. Ser. X, 2 (1934), pp. 39-218. The additional literature will be found referred to in those publications.

Table 75

Place	Period of Time	Total rainfall per year in mm.	Rainy days per year	Months with a rainfall of less than 60 mm.	Months with a rainfall of more than 100 mm.	
(No. 384) Koekoe	1913-1928	2175	151.2	0	11	
	1930	1264	87	8	2*	*in which 1 month (April) with 789 mm.

The last-mentioned, ultra-basic rocks, however also occur behind Kolonodale, and again and again in many places as far as the gulf of Tomini.

Climate

The already repeatedly referred-to book by Braak[91] states on page 451: "The complex mountain system of Central Celebes has, as a consequence, marked local differences in climate. The available data are, however, quite inadequate to give even a partially complete picture of it."

As far as Central Celebes as a whole is concerned this is still the case. We are able to give below but little information in the form of a description of the unusual climate of the Paloe valley, as well as some notes on the region around Poso Lake.

In a land such as this right under the equator the monsoons in general are weak; more especially in the center of the island, in the vicinity of Poso lake. On the coasts there are land and sea breezes, and in the interior, mountain and valley winds.

In Central Celebes it is neither warmer nor colder than elsewhere under the equator. But since the differences in elevation are considerable, some differences in temperature occur. Large areas of land lie above 1,000 m., quite considerable above 2,000 m. and a few peaks reach elevations of around 3,000 m. The corresponding average temperatures are about 20°C, 14°C and 8°C, as compared with average temperatures for the lowlands of from 25.5 to 26.5°C. Since it is usual that the spread between maxima and minima becomes greater with increasing elevation, we may conclude that night frosts occasionally occur in the high mountains, even if the air is not extraordinarily dry.

If we calculate the average rainfall figures for more than 10 years for the greater part of Central Celebes (excepting the Paloe valley and the southwestern corner at Madjene) the monthly averages for at least 9 months of the entire year are more than 100 mm. The driest 1 to 3 months have between 60 and 100 mm. of rain. Basing conclusions upon this, we would at once deduce that the "soil is always wet, with continuously downward water movement and leaching." But if we take a striking example such as Koekoe, lying south from Poso, then from the figures published by the Observatory at Batavia it is evident that the conditions prevailing in the very dry year 1930 are not represented by the average of the 15 previous years for Koekoe (Table 75). The question then naturally arises as to whether or not an average of many years has any significance if it so completely obliterates such severely dry seasons. And should we expect that the soil type would be locally much altered by such an exceptional season?--The answer will depend upon 2 factors: 1st the parent material of the soil itself; and 2nd the frequency of such pronounced dry seasons. Let us consider the latter point first. If for example, very dry and very wet years alternated regularly, then there would not be an annual but a biennial period, which upon impervious parent material would perhaps bring about quite a different course of weathering than would result from an annual and reasonably regular rainfall regime. Contrary to the generally accepted idea, it is not likely that the rainfall is reasonably regular. Now as to the first point; for the weathering of easily pervious

91. C. Braak, Het klimaat v. Ned. O.-Indië, Verh. Kon. Magn. Meteor. Obs., Batavia, No. 8, II (1929).

material there is only this difference, the continuous leaching is now and then interrupted, and takes on a somewhat more intermittent character. The differences in the nature of mature profiles produced by dry seasons will be of but little importance. (See pages 150, 151.) Thus there will not be any serious error in accepting the conclusion that in general, and over a period of many years "in Central Celebes the soil is almost always wet with water moving downward." It is however possible that some bodies of flat land may later appear to have a divergent and apparently drier climate. The plains of Leboni, Selopada (Sekke) and Besoa come to mind in this connection. In the Bada and Napoe plains rainfall is already being measured (at Bomba and Watoetaoe respectively), but regarding especial drought in those places there is not much to remark. Moreover, neither Abendanon nor Brouwer mention droughts, nor in the collected memoirs of "giving over of charge of districts" by civil officers are any of the plains referred to as being subject to droughts.

But the farther one goes into the remote corners of Central Celebes the more different the picture becomes.

In the southwestern corner there are averages which are still quite close to those of Central Celebes, at least as far as one can see from the figures of the stations Somba, Madjene, Tinamboeng and Tjampalagiang (Table 76 below). Although the average total rainfall per year varies from less than 2 m. to barely more than 1,300 mm., yet the average number of "dry" months is one or at most 2, and there are at least 8 "wet" months, although once in a while a severely dry year such as 1930 does occur!

In the northwestern corner of Central Celebes in the Paloe valley there is another divergence in the climate. In this valley there are enough rainfall stations, and they are well enough distributed, so that the figures for Donggala, Paloe, Bora, Kalawaranapoeti and Lemo (Koelawi) give a general view of the rainfall distribution. Because of the west monsoon, and because of the location just around the corner outside of the valley, on the sea, Donggala during 37 years observations averaged but 1 month with less than 60 mm., while 8 months were "wet" with more than 100 mm. rainfall. Yet in Paloe and its immediate surroundings the conditions are so different that almost all months are "dry," and only just one month per year has more than 60 mm. At Bora which lies south-southeastward and higher, at an elevation of 30 m., the average of the past 7 years is 4 dry and 4 wet months. Further on at Kalawaranapoeti, 80 meters elevation, during 12 years there has not been an average

Table 76

DISTRIBUTION OF THE RAINFALL DURING THE YEAR IN A FEW REMOTE CORNERS OF CENTRAL CELEBES

Station	Number of years of observations	Elevation above sea level in m.	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Southwestern-Central Celebes																		
Mamoedjoe	14	at sea level	146	215	151	190	181	216	183	112	100	194	150	213	166	2071	12	0
Somba	12	"	97	252	150	154	202	153	148	94	33	89	107	226	352	1960	9	1
Madjene	23	"	109	200	192	151	179	164	110	87	55	70	119	202	227	1756	9	1
Tinamboeng	14	4	100	150	133	133	182	133	124	62	42	74	97	127	188	1445	8	1
Tjampalagiang	14	5	79	105	120	137	145	143	115	76	42	59	130	103	138	1313	9	2
Paloe Valley																		
Donggala	37	6	97	197	163	157	103	100	126	98	83	67	57	109	140	1390	8	1
Paloe	22	at sea level	81	46	39	47	43	49	63	46	51	42	34	46	40	546	0	11
Bora	7	30	98	50	43	90	83	115	110	66	112	111	64	58	39	941	4	4
Kalavaranapoetih	12	80	132	72	102	122	123	159	154	130	115	141	96	131	75	1420	9	0
Lemo (Koelawi)	15	735	170	134	164	214	253	245	203	199	172	186	184	212	157	2323	12	0

Photo from Kon. Paketv. Mij.

Fig. 134. Looking toward the northeast across the southern portion of Paloe Bay, Celebes. Foreground: xerophytic strand vegetation. In the distance: mountains covered only by pale brown, dead grass. (See pp. 331, 332, 337, 340.)

of even one dry month per year while there had been 9 wet months. Much farther south at Lemo (Koelawi) at 735 m. elevation above the sea, during 15 years all the months have averaged wet months, with an average minimum of 134 mm.

It must be mentioned that the climate of Paloe is described as extraordinarily hot. Braak[92] says: "All reports speak of great heat during the day....," while Steup[93] gained a "general impression of dry heat. If one rides around here, he forgets entirely that he is here in the Indies, and seems to think that he is making a journey through the dry portions of the U. S. A."

Ways in Which Weathering Occurs and Resulting Soil Types

From the above it follows that in Central Celebes the variation in soil types ought to be ascribed more to differences in the parent rocks than to differences in climate in combination with the monsoons.

In this part of the Celebes there is but little fresh, loose rock material which has resulted from volcanic action. Practically all the rocks were originally compact and solid. The granites (using the term in the broad sense) of the Molengraaff Mts., for example, are certainly solid when they are fresh. The schists of the Fennema Mts. are also solid, as are the limestones (many times really marble). But east from Poso lake the rocks become less solid and, among other things in that region, looser sandstones and weaker marls and clay stones occur over great areas. Within the region of the schists Brouwer[94] mentions the formations in the west as having been more strongly metamorphosed than those in the east.

Any great differences between wet and dry seasons are lacking. Great temperature differences are likewise connected with desert conditions. There can thus be no strong physical weathering. The rocks

92. C. Braak, Het klimaat van Ned.-Indië, II, p. 452.
93. F. K. M. Steup, Paloedal, Tectona XXII (1929), p. 583.
94. L. c., p. 52.

weather chemically, and for the most part in the presence of a surplus of moisture. But whether there is much, little, or almost no water percolating downwards from above, depends upon the kind of rock and the degree of "decomposition," and whether the weathering mass first formed from it is pervious or not. As has already been said repeatedly, <u>the degree of perviousness of the weathered material depends upon the amounts of quartz, iron, and lime in the parent rock</u>.

There is an additional important factor, and that is whether the loose weathering material first formed is easily attacked and separated by erosion, or whether it remains lying long enough in one place to develop a distinct soil profile. However, regarding this there are practically no sufficiently accurate numerical data recorded.

Of those who have travelled through Central Celebes, Abendanon is the only one who, in describing his journey, recorded anything about the soil. Thus in the narrative relating to his trip from Masamba northward[95] and then the further march from Gintoe toward the northwest, there are repeated references to a light gray colored sand, originating from granite. On this granite one would most probably expect lixivium with light brownish yellow to light red tints. However, presumably because of a low iron content, only "grayish soil is mentioned, with much sand".lying on the surface. It is obvious that at elevations of 500 to 1,500 m. and more, where travel narratives state that heavy rains are a daily occurrence, the feldspars would disintegrate first, resulting in the rocks being broken and crumbled to quite considerable depths. Then one might suppose that erosion would carry off the loose fragments of quartz mica and feldspar more rapidly (page 574), rather than that the granular mass would be transformed into a brownish yellow and ultimately into a red lixivium.

Along the road between Rantepao and Paloppo (about which more later) I noticed that in a corresponding climate and at a similar elevation the first weathering phenomenon to be observed on granite was disintegration connected with the feldspars becoming milky and the developing of a light brownish-yellow coloring surrounding the darker hornblende and mica minerals. But the structure of the rock was completely preserved; only upon hitting it with a hammer did it fall apart to a coarse sand. Weathering had progressed in this locality to a brownish yellowish gray sandy lixivium and even red, sandy lixivium (see Fig. 139, page 360). The humous surface soil did not show the brighter tints so well, and was predominantly a yellowish gray to brownish gray. It is thus possible that Abendanon had actually followed a route over a granite terrain, which consisted of brownish yellow to red lixivium under the surface soil, but which he did not see. However since he wrote: "On the small ridge, in which the path had sometimes been cut and washed out to 1 m. deep in the granitic sand, we found even just in front of Masaroe great blocks of light-colored granite...." we may presume that at that spot the weathering had not progressed beyond the first stage.

Apparently the granite of Central Celebes has a strong tendency toward rapid disintegration. In other parts of the earth, even in the tropics, granite is one of the most resistant rocks and granite nobs remain as great boulders standing out above the landscape. On the Seychelles Islands[96] and the coast of Guinea[97] in the course of a very long time a thick layer of red lixivium and laterite is formed on granites. What causes the difference?-- The petrographic investigation of Gisolf, who worked up the rocks of Abendanon, brought out the factor[98] that the rocks from the Molengraaff Mts. possess considerable quantities of myrmekite, presumably originating as the result of pressure. If in this we take into consideration that according to Gisolf[99] "it seems to be quite definite that the granite batholith of the central range of Central Celebes is not yet

95. L. c., dl. II, pp. 573-590, and 766-775.

96. M. Bauer, Beitr. Geol. Seychellen, etc., N. Jb. Min. etc., 2 (1898), 163-219.

97. A. Lacroix, Les latérites de la Guinée, Nouv. Arch. Mus. Hist. Nat. 5, V (1913), pp. 255-356, (Paris, 1914).

98. Abendanon, Geol. en geogr. doorkruisingen v. Celebes, III, pp. 1020-1027.

99. See Abendaon, l. c., III, p. 1027.

so far denuded but that the myrmekite and micropegmatite-containing rocks formed in the head still remain preserved" while Brouwer in his last publication regarding Celebes[100] repeatedly calls attention to the "mylonetic zone," in which the granites etc. referred to, lie. Then there are indications that these rocks have been disturbed and so are less solid than their namesakes from less "agitated" parts of the earth.

However this may be, according to Abendanon the rivers coming out of the granitic region carry much sand, and are not clear. The plains of Leboni, Bada and Besoa then must have been lakes filled up with detritus principally from granite and it is by no means unlikely that other rocks have also contributed to this. Referring to the latest sketch map of Brouwer, this is obvious, especially as regards the plains of Bada and Napoe. Also the size of the coastal plain in front of Masamba, in comparison with the plain which is much less developed more to the east, calls attention to the probable relation of this to the rocks of the Molengraaff mountains which rapidly break down into coarse sand.

The Fennema Mts. give an entirely different picture. In these mountains according to Brouwer there can be differentiated:

a. an easterly zone, with crystalline limestones and calcareous phyllites; ....and
b. a westerly zone, in which calcareous rocks are entirely or almost entirely lacking.

According to the descriptions by Abendanon and Brouwer, the Fennema Mts. are a peneplain which has been elevated more in the west than in the east. In the east near Poso lake it is only about 1,000 m. high, while in the west it is about 2,000 m., with a number of low peaks reaching to as high as perhaps 2,200 m.[101] While the terrain over great areas is only little incised, this high plain can be pictured as slightly irregular. It does not remind one of anything else in the Netherlands Indies. The reddish-brown water indicates a low pH and hence acid soils presumably poor and infertile. This is in agreement with the paucity of the population. In the miserable tree vegetation Podocarpus and other allied species predominate. On the soil is found much Sphagnum in the form of the well known cushions. While crossing this plateau one gets very wet in the weak, sloppy soil, a true, black peat bog. Here and there one stumbles upon some gravel, snow white small fragements of silica. Depending upon the depth, the pools and ponds appear dark brown to black. In short,--all the earmarks of a peat landscape are present.[102] Brouwer even mentions (l. c., p. 119) "long peat bridges," constructed at different places along the way. Valuable botanical observations may be found in Steup's descriptions[103] of a march through the Fennema Mts. All writers mention the white rocks which occur in this high peat tract, but it doesn't come into the head of the forest officer to say even a word about the soil as such. How very interesting it would have been if Steup had but just dug a pit and had described the soil profile at that place about which he writes as follows: "Here we travelled, as in the Brabant fens, over a springy Sphagnum surface, where the water comes up into the foot prints. As far as I know, high peat formations do not occur very frequently in the Indies....."

However, not all the kinds of rocks which make up the Fennema Mts. provide proper conditions for the existence of peat. At another time Abendanon noted at about 1,000 m. elevation an "orange colored clay, through which was mixed pieces of white quartzite" (p. 596). Later, in referring to another locality at a much greater elevation, perhaps even 1,800 m. he also speaks of "muscovite schist, the weathering of which had sometimes gone so far that orange colored clay had been

100. Brouwer, l. c., p. 126.
101. On the map of 1919 are indicated summits of around 2,000 - 2,100 - 2,200 - 2,300 m.; on the reprint of 1927 these elevations were not altered. The topography as delineated on this map, however, does not seem to agree very well with the descriptions of the landscape.
102. Abendanon, l. c., pp. 594-606 and again pp. 735-738.
103. F. K. M. Steup, Tectona XXIV (1931), pp. 1122-1130.

formed." (p. 594). Further on toward the east he saw a "phyllite, sandy powdery and weathered to a light cinnabar red color." (p. 607). These observations indicate that the conditions for the formation of peat in the tropics are very limited, and that with but small changes[104] in the composition of the rocks and a few hundred meters less elevation there is a quite rapid change into the zone of yellow to red lixivium. Simultaneously the dark brownish red color of the river water disappears. The waters are colorless though of course at times they are turbid, being colored by the material in suspension.

Turning now to consider the conditions to the east of Poso lake, we find many rocks softer, so that they weather more easily and hence soil formation can keep farther ahead of erosion; there is therefore more soil. In this region the elevation is less (about 500 m. instead of between 1,000 and 2,000 m.). There is much rain with many wet months. Therefore an abundant opportunity for the formation of yellow, brown and red lixivium exists. That this is indeed correct is confirmed by Abendanon's records, as follows:

a. "blocks of light gray, crystalline micaceous limestone....and bluish gray limestone project up through very fertile yellow clay soils. The region is a cogonal one (i.e. covered by cogon, Imperata spp.)" (p. 610);
b. "sericite schist, which can be cut with a knife....more or less completely weathered to a yellow and red sandy clay which feels greasy to the touch," (p. 610);
c. "mostly a distinctly purple weathered talc mica schist, thin bedded, sandy powdery, yet with a silky lustre" (p. 611):
d. "low outliers of the surrounding hilly land in the plain of the Masewe River: light wine-red clay soil with dimly purple and blue schist and phyllites"...(p. 612), purple and rust colored weathered (p. 615);
e. a "red weathering clay cover," up through which "purple weathered phyllites" and "heavy light rose and yellow clay slates project" (p. 616);
f. "great blocks of purple brown, hard, thick limestone lying on heavy brown clay soil." Finally, when he came onto basic, iron-rich rocks, he found
g. "weathered serpentine, in coarse fragments, colored grayish green and brown originating from harzburgite. The soil consists of....dark reddish brown laterite....on a peridotite which is weak because of holes being weathered in it (the result of the disappearance of the olivine)...." (p. 625). Most probably the "reddish brown laterite" is what in this book I am calling a reddish-brown lixivium or red earth.

Also north of Tentena, Abendanon noted that "locally the schist was weathered to a red heavy clay soil" (p. 682); but on a "2 meters high bank" of the Poso lake, near Tentena, the transition to subaqueous weathering was visible, since he described this bank as "consisting of orange and blue clay and sand, a kind of clay which naturally originates from the weathering products of the schists." (p. 699).

It is noteworthy that the Koia river, which flows out of the schist region with turbid, red water into the Poso lake (p. 699) gave occasion for the following remarks: "The calcareous lake water brings about a precipitation of iron hydrates, which makes turbid the river water close to the lake. I do not believe that it is too risky to try to explain in this manner the origin of many of the existing occurrences of limonite, from which the natives in Central Celebes outside of the peridodite mountains make their iron tools" (p. 709). These remarks recall what he had previously written (p. 600 and 601): "Bangga village had a small iron smelter..... Also at Sapelemba there was a small iron furnace. According to the reports, the brown and yellow swamp iron ore used there was being brought from the Waliane district to the south of Sapelemba. Presumably Waliane

104. Whether these changes in composition are actually so small as one might presume from the petrographic descriptions alone is still very much a question; particularly since there are absolutely no analyses of any of these rocks.

is also "in a depression, where an old lake had been" (Abendanon had previously been speaking of the flat basin of Rato (pp. 597-599) which must have been a lake) ..... In the light of the general discussions in Part I above, the observed facts as here recorded can be explained without difficulty as a consequence of the alteration of the pH from lower than 5, to higher than 6, perhaps even to well above 7.

From the descriptions by Abendanon a few more examples might be mentioned here: To the north of Paloppo he continued his way "over a gray sandy soil, which was a weathering soil of granite or trachyte" but "the soil began to be red and sandy clayey" and "already heavier and more clayey where dissected basalt was recognized as the solid rock..... The bed of the Polambaja river was filled with large blocks of diabase. Even this very hard rock weathered to a very heavy clay" (p. [illegible]). Whether as would be supposed, this soil also was red, is not stated. The soils derived from basalt and diabase had a heavier forest cover than the other soils on either side of them. As Abendanon says: "here we see how closely the nature of the forest is connected with the occurrence of a definite sort of rock." (p. [illegible]). This is a fact with which foresters have long been familiar.

Dacite tuff from the Rarawana mountains appears to be covered over with a brick-red weathered clay (p. [illegible]). In short--in as far as anything has been recorded it appears that almost all rocks of Central Celebes, no matter how widely they may differ in their nature and composition, seem to be covered by practically the same weathering soil, varying from yellow to red and brownish red, a soil which in general we can characterize as a subaerial lixivium, more or less sandy, and in age from relatively juvenile to senile.

Several times Abendanon had noted (pp. 586, 766, 772, and 800) that the higher he went, the more humus he saw in the surface soil. This is exactly what we would expect.

If we now ask whether there are not some other types of weathering to be observed, the answer is that the climate affords little or no opportunity for other kinds of weathering. In Paloe, at least close to the town of this name, a priori one might expect black earth. It should be considered that the Paloe plain has only relatively recently been uplifted and that a large portion of the plain has been covered with sand and gravel, which has come down in recent times from the surrounding mountains and is spread out at their feet in sizeable rubbish fans ruining a large proportion of the paddy fields. Therefore there is not very much space left where we could expect to find even moderately well-developed black earth.

However, it seems to me there is a reasonable chance that some may be found. Didn't the Sarasins write in their diary[105] about herds of sheep, which at sunset hurried to the village, and from the flock such dust rose into the air, "on the dry, gray steppe--an almost African picture?" Thus gray is the color, or grayish.--Just a little farther on they write about a place already south of Dolo, where looking out toward the north, the valley appeared like "a picture of a large orchard or park."[106]

This park landscape is well known from its frequent occurrence along the northern coasts of the Smaller Soenda Islands where its soil is always a black earth or gray earth. The photographs which Steup,[107] the forester, has published in his paper devoted especially to the plant geography of the Paloe valley, makes one think at once of such a park landscape, although he does not say a word about the color of the soil. The closest he comes to it is where he speaks of it as "hard, bare ground." He only records[108] the words of Bruinier (1922), who reported a "very stony terrain, with a growth of cogon (Imperata sp.), blackish ground, also a little scrub ....." Here for the first time we find the word black (ish) used by an eye witness. Closer inquiry to confirm or contradict this description is indeed very necessary, so that it can be determined, whether the water movement is intermittently

105. P. and F. Sarasin, Reisen in Celebes, II (19[illegible]), p. 1[illegible].

106. Idem, p. 17.

107. F. K. M. Steup, Paloedal, Tectona XXII (1929), p. [illegible].

108. L. c., p. 989.

downward, or moving alternatingly downward and upward. It is of course recognized that the nature of the water movement determines the nature of the whole weathering process.

Regarding subaqueous forms of weathering, a few things of one sort and another have already been mentioned incidentally. Subaqueously weathered soils obviously occur in the mountain basins and existing lakes, for example south of Poso lake and Pendolo, where Abendanon (p. 608) came across "heavy clay." More easterly, at the village of Lee, he crossed "a cogon (Imperata sp.) plain with black humus soil in which were small white silica stones" (p. 614). This last can be an indication of the leaching out of the iron under previous marsh conditions.

That amphibian forms of weathering must be found in a number of places is obvious. Examples of lake plains that have become dry are Leboni, Rampi, Bada, Besoa, Napoe, Gimpoe, Lemo, Rato and Wahane. Others occur between Pendolo and Kolonodale. Finally the large coastal plain around the gulf of Boni, which at Masamba is fully 35 km. broad, should be remembered.

There is also the terrain of the allochthonous soil types. In the west there is the low Masamba plain, a large part of which has been formed from detritus which has been carried out from the granite and diorite region lying back of it. In the center, detritus from the schists of the Fennema mountains and of the Tamboke mountains which lie more to the south has been deposited. In the east in the plain of Wotoe there is also schistose material. In the east much weathered material has been deposited which was derived from serpentine and peridotite and the lime and marl which overlie these.

It is true that quantitatively and qualitatively this coastal plain exhibits great differences between Paloppo and Malili. The granites of the Molengraaff Mts. (see above, pp. 330, 333) disintegrate very easily. They thus supply the most rock detritus and weathering material. Via the Rongkong, the Masamba, the Baliasse and the Lampoeawa rivers this material has been transported and deposited in great quantities to build up the broadest part of the coastal plain. Consequently the soil consists of alternating layers of gravel, stone, sand, loam and clay. In general the color is pale, with a somewhat reddish brown tint. The soils which occupy continuously dry positions are redder, while the lowest parts are paler, though some darker soils with a higher humus content do occur.

In general it may be accepted that the soils are on the sandy side. In the north, in the vicinity of Masamba, quartz sand makes up a large part of the soil, although mica always occurs in it. The heavier types are not more than loam and heavy loam, since the content of quartz flour and small flakes of mica is too high for a clay soil to occur. An example of such a soil is found in the repeatedly mentioned publication of Van Harreveld-Lako and Arrhenius[109] where they report the mechanical (granular) analysis of a "light clay collected in the forest near Patimang, about 27 km. south from Masamba." The figures are given in Table 77 below.

More properly we should call such a soil as this, of which 3/4 lies between 100 and 5 mu, a light fine sandy loam soil, and not a clay (although for a brick maker this material would certainly be an ideal "clay!"). Also other samples in the above-mentioned publication (on page 824) are designated as "clay," a term which gives an impression different from what the textures really are. Since all samples possess a high content of fine sand and coarse sands, as well as of mica scales,

Table 77

No.	2-1 mm.	1-1/2 mm.	1/2-1/5 mm.	1/5-1/10 mm.	1/10-1/20 mm.	50-20 mu	20-5 mu	5-2 mu	2-1/2 mu	Less than 1/2 mu
2968	0	0	1%	2%	24%	33%	18%	10%	7%	5%

109. Meded. Proefst. J. S. I., No. 18, Arch. Suik. Ind. Ned.-Indië (1927), pp. 820-825.

it would seem more appropriate to designate them as light to moderately light loams, more or less sandy.

Farther to the east, in the so-called plain of Wotoe, though there is quite a good deal of quartz in the form of coarse sand, besides some mica, there is less sand in the soil. This is what one would expect of material coming from mountains in which phyllites and mica schists are the most important rocks. In the mechanical analysis this results in a shoving of the maximum one fraction toward the fine sizes; that is, from sand and sandy loam to fine sandy loam, from lighter loam to heavier loam, from heavy loam to clay. Even here and there to peaty clay.

All these sorts of soil have the common characteristic that when they are moistened with rain or by flooding they rapidly become saturated with water, and then become easily movable. On a road across a loam of this kind every vehicle sinks in to the axle, each footstep becomes a sopping wet pit. On the other hand after one or two dry days this loam is again solid, so that the road once more becomes passable and practicable for use. The closer, however, the soil comes to being a real clay, the less disintegrating is the effect of a moistening, but also after the clay is once wet the longer the effect lasts before the soil again becomes really dry, and practically passable.

The most easterly part of the plain, composed of material from very basic rocks is better considered in connection with the discussion of these rocks and their weathering (see pages 349-351).

Evaluation and Utilization of the Soils

Since there is not only a lack of adequate data, but also as far as is known, there is little variation in the soil, the treatment of this topic can be relatively brief.

The greatest part of Central Celebes is still heavily forested; though in the course of kaiñgin agriculture considerable portions have been cleared. As is usual such treatment, followed by repeated burning, has transformed the cleared areas into cogonals.

A relatively small portion of the land has been laid out as lowland rice fields. Various factors may be noted as seeming to have determined where these paddies are located. In the first place they were located on the plains which were formerly lakes or ponds, and in the second place the coastal plains were used.

Abendanon recorded[110] that the inhabitants of Leboni "were busy with maize planting in the gardens lying round about. Rice was cultivated only very seldom and yet the plateau of Leboni would make first rate rice land." This opinion seems to me to be hardly correct. It is more likely that rice was once tried there but was not successful. "The Leboni river carries off much granitic sand into the plain" says Abendanon. Such sand is indeed a danger for paddy fields. Moreover, if there were paddies there, how could they hold water on this sandy soil where water sinks away so rapidly? While the water capacity is perhaps adequate for maize, yet rice, even upland rice, needs more water. Presumably at Leboni there is the same danger, also, as in the wide plain of Masamba, which is built up of the same sort of material. Also there is the uncertainty of a regular, abundant water supply, and if, even with canals, adequate water were obtained from the rivers, then there is great danger that the rice fields will be quickly buried under sand. Abendanon considered this plain of Masamba very promising, for he said "It could be made into the rice barn of Central Celebes."[111] It is still very much of a question as to whether or not this optimistic expectation can be realized so simply. At present, 20 years later, this plain is for the greater part still well forested, an abode of delight for countless wild carabao. It is true that there are a few paddy-fields, but their extent is quite limited. Just to the south west of the Rongkong river lies some land which is built up of weathering material from other rocks than granites, that is from diabase, basalt andesite, and dacite. The soil, because of better water capacity, is

110. L. c., p. 587.
111. L. c., p. 578.

suited to the cultivation of upland rice and bananas which find a ready sale at Paloppo.

In the schist region of the Fennema Mts., Abendanon traversed the Rato basin[112] which lies at about 1,000 m. above the sea. He reported a "very heavy and moist, practically horizontal clay soil....the valley floor was entirely occupied by paddies." These rice fields will presumably not produce any bumper harvests, for it is not likely that the schists are rich enough. In the coastal plain built up of schistose material, near Wotoe, from the Lampoeawa river to the Kalaena river, according to analyses by Van Harreveld-Lako and Arrhenius[113] "the phosphorus content is low." That is an important factor for rice. The last mentioned workers also state: "The Wotoe plain is more sparsely populated than the Masamba plain, and a large part of it is covered with tropical high forest. Paddies are practically non-existent though there are kaiñgins in the neighborhood of the widely-scattered villages."--No longer can such a statement occasion surprise. The soil is apparently poor, although it is perhaps physically better suited for paddy than that which lies more to the west in the Masamba plain.

In the Poso valley, between Poso and Tentena, lowland rice (paddy) cultivation is possible everywhere. This is also true of the flat lands north and south of Poso lake. Thus far we have had no luck in finding any data regarding yields which would indicate something about the fertility.

In the tract between Poso lake and Kolonodale there also appear to be quite a few paddies, but in the northeastern corner of Central Celebes there are only kaiñgins.

The history of Paloe is interesting. During the time of Rumphius the entire valley was nothing but paddies. Apparently the slopes of the mountains to the east and west were not then deforested to such an extent as they are today. This deforestation has been completed during the last century (see Fig. 134) with the consequence that when spates occurred in the rivers the land was covered over with sand and gravel, so that now between times of high water there is either no water flowing in the rivers, or else all the water rapidly sinks into the sand and gravel, to again appear at the surface close to the sea. Also farther north of Tawaeli there is adequate moisture in the soil to make possible a decent growth of vegetation over the entire plain from the sea to the mountain ridge, which may be thought of as the spinal column of the neck of Celebes. But northeast, east, and south from Paloe "behind the coastal strip of partly white coral sand, part dark sand and gravel, there lies black or yellow clay upon a deeper layer of sand and gravel."[114] There is no lowland rice cultivation in this valley. Only after the mountain slopes are again reforested and, consequently, the freshets controlled, will there be any sense in trying to extend the paddies.[115]

As to the possibilities for plantation crops in Central Celebes, not many experiments have yet been carried out. A coffee plantation which was started behind Madjene, thus really in the remote southwestern corner, was, after a short time, abandoned. North from Wotoe a few years ago a coco plantation led a very problematical existence. In the good years before the crisis a large company had explored the coastal plain along the gulf of Boni but in spite of the explorations it did not dare to establish new enterprises. Even if the golden years of olden times came back, we would still be unable to point out in this part of Celebes any lands suitable for European plantations.

Let us now consider the tropical high forest. For years it has supplied much rattan and dammar. Now there is so little profit in that business that the exploitation has been very much reduced, which is certainly all to the good for the natural regeneration of the dammar trees and of the rattan. Until recently, ebony was also obtained, especially in the Poso

112. L. c., pp. 597-599.
113. L. c., pp. 822-825.
114. Note on the occasion of giving over charge, by Controller C. H. ter Laag (July, 1920), p. 6.
115. Cf. also: Steup, Tectona XXII (1929), pp. 587-590.

subdivision.[116] The mention of ebony arouses involuntarily the following association of ideas: hard wood--slow growth--on poor soil, which is certainly true for the forests where it occurs.

Central Celebes is sparsely populated. Is this the case because it is a "forgotten corner?"--or because this region is not able to support more people? The latter is true in various parts of the earth, even in many parts of Europe. Where the soil does not yield a good enough living, the density of the population is low.[117] Lucky that elsewhere Celebes offers so much more opportunity for development!

4. The East-Northeastern Peninsula of Celebes.

Soil-Forming Rocks

From various geological investigations[118] we already have some material to give us a proper orientation regarding almost all the coastal regions and of the entire easterly part of the peninsula here referred to, but regarding the interior of the broad westerly part we, as yet, know practically nothing. However, from what we already know it appears that there is quite a great deal of variety in the parent rocks from which the soils have developed.

Over great areas occur igneous rocks, especially basic ones, diabases, gabbros, peridotites. Also diabase tuffs occur in the hinterland of Boealemo. In addition to these, but in only a couple of places, near the center of the northern coast, are crystalline schists. In the eastern part, as in the central mountain ridge, and at a number of places along the coast, there are also older, especially Tertiary, sedimentary rocks such as sandstones and conglomerates, marls and limestones. In these, however, there is also some eruptive material, so that one can many times speak of tuffs and tuffaceous marls and sandstones, mentioning particularly the so-called "Celebes-Molasse." Great portions of the eastern half of the coast consist of upraised young coral reefs.

But as far as is known, young volcanic formations, such as in Minahasa, are entirely lacking here.

Thus far in the literature I have found no analyses of the rocks.

Climate

Through direct observation and publication of the results there is still but little known about the climate. There are only 3 stations measuring rainfall--Tobelombang on the north coast, and Loewoek and Tokala on the south coast. At these three points the rainfall is so divergent that any general conclusions, applicable to any large portions of the peninsula, ought not to be deduced from them. Note that with an annual average of 1,541 mm. (during 12 years), Tobelombang has a lowest monthly average of 72 mm. contrasted with a maximum monthly average of 173 mm. On the average, the soil climate will thus be continuously wet. Loewoek, on the contrary, with an annual average of only 922 mm. (during 21 years), has 3 monthly averages under 60 mm., thus with a distinct dry season. Yet it has but 3 monthly averages above 100 mm. and with a maximum average of only 122 mm. This locality lies in the rain shadow of Peling. On the other hand Tokala, also lying on the south coast, but not in the rain shadow of Peling, seems to receive quite a good deal more rain than Loewoek. (The observations at Tokala at most run only for a short time and are far from complete.) In 1929, for example,

116. See F. K. M. Steup, Bosschen van Noord-en Midden Celebes, Tectona XXIII (1930), pp. 857-873.

117. It is obvious that mining, manufacturing and commerce can blur that picture, obscure it, or even reverse it. The places where it applies are in agricultural production; and the density of the population on the land. Examples: Norway, Scotland, the plateau of Spain.

118. M. Koperberg, Bouwst. Geol. Resid. Manado, Jb. Mijnw. (1928), Verh. II, pp. 418-446; I. Wanner, Beitr. Geol. O-arms d. I. Celebes N. Jahrb. f. Min. etc., Beil. Bd. XXIX (1919), pp. 739-774, references to authors in: 4e Kolon. Vac. curs. v. geografen (Amst. 1923); W. C. B. Koolhoven, Versl. Verk. tocht O-arm Celebes, Jb. Mijnw. (1929), Verh., pp. 187-228; H. A. Brouwer, Geol. Onderz. eiland Celebes, Verh. Geol. Mijnb. Gen., Geol. Ser. X (1934), pp. 39-218.

about 4,000 mm. rain fell at Tokala as contrasted with only 617 mm. at Loewoek. In this latter place in all of the year 1930 but 334 mm. fell.[119] Thus in these regions, from year to year and from place to place, there are enormous differences in the rainfall. As to the interior nothing positive is known, so that it is possible that on one side there are places with continuously wet soils in contrast to places on the other side, (for example valleys extending northwest and southeast) where regularly annual drying out of the soil can occur.

Ways in Which Weathering Occurs and Resulting Soil Types

There is little tangible knowledge regarding the rocks and the climate, but still less can definitely be said about the soil types.

Southeast from Oeë Koeli, that is on the northern coast of the western part of the peninsula now under discussion, serpentine schist occurs. Koperberg[120] in discussing it, says: "This schistose material is the predominant rock. It is mostly thoroughly weathered and of an orange brown color. This is also the prevailing soil "color." And speaking of the mountainous land, which lies northeastwards along the coast he states,[121] "The Oeë Rate massif as well as Mt. Kinajombi are similar and have a somber brown color like Mt. Pangkanka and the other mountains of the coastal series of Banano and Oeë Dele. These must all be peridotite."--As far as I can learn these are the only two places in the exhaustive treatise of Koperberg, in which anything is said about the soil.

It is to be expected that on these ultra-basic rocks very rich in iron, the color of the weathering soil should be of a brownish color. If the process is being effected by oxygen-containing water it makes little difference whether the weathering type is one of continuous leaching, or of intermittent leaching. Because of the high iron content, the weathering mass in each stage remains quite porous for both water and air, so that Ca, Mg and Si can be washed out more or less rapidly. The iron oxyhydrate with accessory substances such as aluminum oxide, titanic acid, manganese peroxide and perhaps still other metallic oxides remain behind. Hence, such a soil when it becomes senile, must, indeed become quite poor and as a consequence carry only a very miserable vegetation, especially when the soil climate is such that the soil remains continuously wet, or at least moist. If, however, the climate is such that each year dry winds can blow dust onto the soil, for example from regions with weathering marls and limestones, then while there will hardly be a luxuriant vegetation, the soil can carry a closed forest. However, if that forest is "kaiñgined off," then the chances of recuperation are very small.

It is to be regretted that there is not a single travel narrative by a soil scientist travelling through the strip along the southeastern coast of this peninsula from Kolonodale to Loewoek. In the work of Koolhoven, the geologist, to which we have referred, there is not even the slightest reference to the soil. Yet, because of the great diversity not only of the parent rocks but also of the climate in that region there must certainly be very clear soil differences to be observed. Hence, if hypotheses be in order, we might mention the following: In the plain of Morowali-Tokala, which presumably is mostly covered with tropical high forest, we could expect to find an iron concretion formation developed on a big scale at the boundary between the layers which are always adequately aerated and those which always lie under water and are thus deprived of air. Higher up, reddish brown lixivium would occur while toward the sea, fat greenish gray clay would be found.

In the plain of Toëli one would expect loam, varying from heavy to light (more sandy) and of greater fertility. The natural vegetation would be tropical high forest.

On the probably barren or poorly forested hilly land back of Loewoek a grayish brown to grayish black granular earth

119. Such a minimum, with 11 "arid" months is certainly something very unusual in the Netherlands Indies.
120. L. c., p. 424.
121. L. c., p. 428.

may be expected, which will be quite thin on the ridges, but where it has accumulated by washing or blowing in, depressions will generally be of great fertility, if there is sufficient water.

These are all only deductions or suppositions, which, at most, can serve as a goad for closer investigation. Since in the enthusiasm for new land for colonization on New Guinea, exploration has continued, it seems to me that there is good reason for closely examining regions lying nearer at hand, such as this portion of Celebes which is so thinly populated. For soil exploration, especially the coastal portion between Rata and Loewoek, as well as the northern coast of the Boealemo peninsula should first be considered, since the so-called "Celebes-molasse" is an important parent rock. And according to Koolhoven,[122] in addition to marls and limestones also conglomerates, breccias, and tuff sandstones occur with gabbro, diabase, and andesitic material.

Evaluation and Utilization of the Soils

Practically the only two experiments in utilization of the soil in the northeastern peninsula are the kaiñgin cultivation in the interior and the coconut culture along the coast. It is not known whether or not it was because of the soil that the site was selected. But in Kruyt's[123] description of the natives of To Wana, nothing can be found which refers to the fertility of the soil in the large drainage basin of the Bongka river, though very much attention is devoted to the very complex relations supposed to be existing between these people and their spirit world. We who are more interested in the natural science point of view, find almost no point of contact, and are apt to get the impression that the natives referred to do not make even the slightest differentiation between good and poor land. Such an impression, however, would be quite erroneous, because it is in general always true that primitive jungle folk are more discerning in this respect than one is inclined to suppose. But meanwhile, we have learned nothing about the soils used by the To Wana.

It is noteworthy that these To Wana folk are disinclined to live in villages. They prefer to live in their little huts in the kaiñgins and are thus obliged to change their abode with each shifting of their kaiñgins. There must be a reason for this. If the area, which in the course of its existence a family needs, is so great that it is not available around one village, where many families are living together, it would seem to indicate that the soil is quite poor. Or it may be that the daily care in the field to combat the diseases and pests is of such a nature that it is impossible to live at a distance. However it may be,--it is to be hoped that persons who know land and folk well will throw some light upon this question.

Regarding the yield of the kaiñgins, or of the planted cocos, we have been unable to find anything.

In economically favorable times the natives collect rattan, dammar, and ebony wood from the forests. But it has apparently not been recorded in which localities the rattan, dammar and ebony trees grow by preference, and in larger numbers.

2. The Peninsula of Southeastern Celebes

In relation to Central Celebes, which we discussed on pages 330-340, we here consider the peninsula extending out toward the southeast, as well as Moena, Boeton, Wowoni'i and Kabaëna, the islands which in various respects constitute a unit with the southeastern peninsula.

Soil-Forming Rocks

Making use of the geological sketch map of Dieckmann and Julius[124] supplemented and improved by Koolhoven[125] in so far as

122. L. c., pp. 199 and 208.
123. Alb. C. Kruyt, De To Wana op Oost-Celebes, T. v. Ind. T. L. en V. k., 70 (1930), pp. 397-626.
124. W. Dieckmann and W. M. Julius, Algem. geol. in ertsafz. v. ZO-Celebes, Jb. Mijnw. (1924), Verh., pp. 11-63 (with maps).
125. W. C. B. Koolhoven, Geol. v/h Maliliterrein, Jb. Mijnw. (1930), Verh. III, pp. 127-153 (with map).

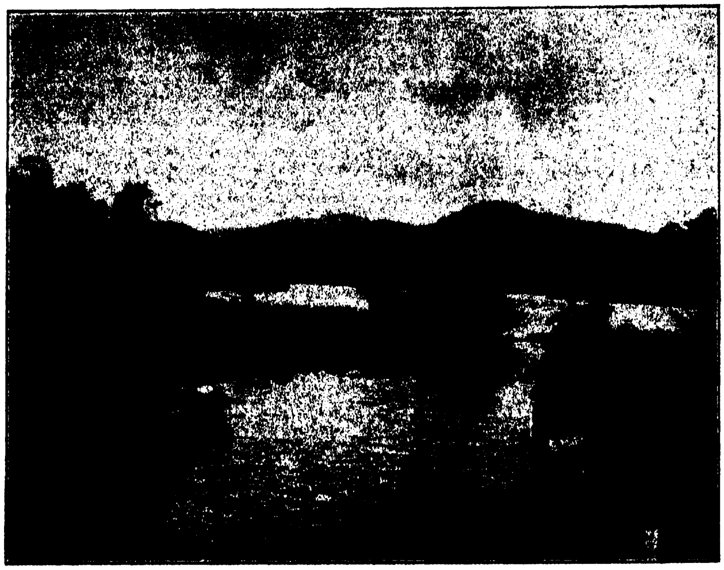


Photo by E. C. Abendanon

Fig. 135. Southeastern Celebes. Verbeek Mts. seen across lake Matani, on the shores of which is a vegetation of poor grasses on laterite alluvium. On the distant mountains of peridotite are lateritic iron and nickel ores.

it relates to the Malili terrain, and by Bothé,[126] for the portion dealing with the southern part of the peninsula referred to, besides the islands mentioned above, we can give the following short survey:[127]

In the north, the Verbeek Mts. are largely made up of very basic eruptives, different varieties of peridotitic rocks, with olivine and rhombic or monoclinic pyroxene as the principal minerals.

In that part of the main island of Celebes to the south of Verbeek Mts. crystalline schists appear at the surface especially in the south western portion. In the northeastern portion, and southeast of there, are paleogenic limestones, marl shales, claystones, etc. as well as great quantities of peridotites.

In the southern part, on Moena and Boeton there are many Neogene sandstones, marls, and clay shales. The farther south one goes, the more young coral limestone occurs. This is true of the mainland both in the southwest, as well as in the southeast, and there is much of this coral formation on Moena. There is somewhat less on Boeton, with much on Wowoni'i but almost none on Kabaëna.

On the surface, Moena exhibits almost no basic eruptives or old schists. Boeton has a few places where peridotite appears at the surface and there is a little schist in the north. On Wowoni'i there is a central core of peridotite, around it some schists, and further out Neogene and coral limestone. On the contrary, more than half of Kabaëna consists of basic eruptives, while in the center of the northern half are some schists.

For soil formation the principal rocks are thus the peridotites, the crystalline schists, and the sedimentary rocks, beginning with Mesozoic limestone, etc., and ending in Tertiary and Quaternary

126. A. Chr. D. Bothé, Vorrl. meded. betr. geol. v. ZO-Celebes, De Mijning., 8 (Juni 1927), pp. 97-103 (with map).

127. Compare: L. Rutten, Voordr. geol. N. O. I. (1927), pp. 552-568, (small map: p. 559).

conglomerates, sandstones, and clays. In addition to these, the reef lime of the elevated corals along the coast is of importance.

Climate

In his exhaustive work regarding "the climate of the Netherlands Indies" Braak,[128] in speaking of southeastern Celebes, says only that Kendari ought to have an agreeable climate, and that in the Konawi plain which lies behind Kendari, a high temperature prevails during the day in the dry season while it cools off considerably in the latter part of the night. For that matter, one could have deduced as much from general data. It is, however, quite in order to mention how scarce the local data sometimes are, both those relating to the climate as well as those relating to the soil.

Thus there is little else to be done than to make deductions. The Verbeek Mts. are a continuation of those of Central Celebes. They should certainly have some sort of an equatorial climate with seldom or never any dry months. The fact that the land gradually slopes up toward the center where there are a couple of large lakes would favor this type of climate. The rains are almost always abundant; as the land is continuously exposed both toward the west monsoon and the east monsoon, yet there are no extraordinarily high rainfall figures.

The farther south one goes, the greater the opportunity for dry months during the east monsoon, especially on the lee side of the mountains. This region begins around Kendari, and lies especially to the south of Staring bay, around Tioro Strait and along Boeton Strait. Table 78, page 346, drawn up in the usual manner will illustrate these few comments.

As to the effect of elevation, it may be mentioned that since the Verbeek Mts. are not higher than 1,400 m., the climate remains "warm," the temperature not falling enough to cause "temperate," conditions. In from the west coast, in the schist mountains, there are a couple of peaks of 2,200 and 2,900 m. There the climate can be not only "temperate" but even cold." Also on Kabaëna is a peak higher than 1,500 m., but as the area at this elevation is very small the amount of land which has a "cold" climate is quite insignificant. Not much of the rest of the land is higher than 1,000 m., while neither on Moena, nor on Boeton or Wowoeni's islands, is there any elevation as much as this. As a consequence, soil temperatures below 20° C are too infrequent to be taken into consideration here.

Ways in Which Weathering Occurs and Soil Types

Without doubt the most interesting weathering in this region is that of the ultrabasic peridotites. And for two reasons: On the one hand, because these rocks have given rise to the formation of enormous quantities of iron ores containing nickel and chromium; and on the other hand, because here we have rocks which, because of their mineral composition, upon weathering produce practically no kaolin; that is, if the general considerations about the weathering developed in the first part of this book are correct. Meanwhile the possibility of the great economic value of the ores has been responsible for a number of investigations, followed by analyses, so that we are able to present the following relatively detailed discussion of the weathering phenomena of this region.

Under these peridotites of the Verbeek mountains there are (1) dunite, consisting largely of olivine; (2) harzburgite, built up especially from olivine and rhombic pyroxene; and (3) iherzolite, in which besides the minerals mentioned, there is also monoclinal pyroxene. One or the other of these extends over the serpentine that often times accompanies the peridotite.

In the absence of feldspars and micas we are thus dealing principally with the weathering of olivine and pyroxenes. Of the accessory minerals besides magnetite, chromite and picotite might be named. In the subaerial weathering all three of these minerals are unattacked and remain behind as unaltered crystalline grains in

128. C. Braak, dl. II, Locale Klimatologie (Batavia, 1929), p. 455.

Table 78

DISTRIBUTION OF RAINFALL DURING THE YEAR IN SOUTHEASTERN CELEBES AND SURROUNDING LOCALITIES[1]

Station		Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
	Soroako	400	13	177	251	226	339	346	287	240	201	168	106	91	182	230	2666	11	0
Verbeek	Timampoe	300	11'	167	234	189	337	398	281	258	212	199	133	127	220	223	2811	12	0
Mts.	Larona	300	12	---	326	265	389	419	297	249	193	146	134	95	209	223	2945	11	0
	Seseh	273	11	191	277	282	366	275	221	218	151	116	113	79	186	205	2490	11	0
	Malili	5	22	165	279	280	334	346	295	215	178	155	117	129	202	241	2771	12	0
West Coast	Kolaka	at sea level	24	139	192	218	249	226	254	183	129	95	92	135	156	156	2085	10	0
	Mowewe	224	11	138	192	184	194	229	233	171	115	63	73	82	128	91	1755	8	0
	Raterate	280	9	120	162	123	227	186	206	245	117	87	69	61	95	118	1706	8	0
	Boengkoe	at sea level	14	135	206	172	251	277	251	241	182	156	96	84	118	160	2194	10	0
East Coast	Salabangka	"	14	129	221	256	257	277	328	389	251	174	88	93	97	183	2614	9	0
	Kendari	10	22	118	201	192	201	179	199	170	116	*59*	*30*	*18*	69	183	1617	8	3
	Groot-Tobea	3	13	98	202	167	220	168	189	198	66	*24*	*18*	*14*	*34*	117	1417	7	4
Islands	Raha	5	20	118	185	197	242	181	214	201	127	*30*	*30*	*23*	61	158	1648	8	3
	Boeton	10	23	131	250	274	214	179	160	144	95	*26*	*19*	*41*	110	236	1748	8	3

1. With the assistance of figures from Verh. 24 v/h Kon. Mag. en Met. Obs. Batavia, supplemented as far as possible with the data for 1929 and 1930.

the weathering mass.

In the warm moist climate of the Verbeek mountains the leaching out of the olivines and pyroxenes which had been broken up through hydrolysis has had the following result:

The olivine yields magnesia, iron oxide, and silicic acid. The magnesia dissolves and disappears, and the silicic acid dissolves more slowly in the percolating water. The iron hydroxide remains behind. From the pyroxenes the magnesia and, eventually, the lime are carried away, and the silicic acid dissolves more slowly and iron hydroxide is the only substance which remain behind. If the pyroxenes contain aluminum and then, necessarily, also sodium, then the latter disappears just as rapidly as does the calcium, while the aluminum hydroxide remains behind with the iron. If there be titanium in the rock also, then that, too, remains behind, or at most it dissolves very slowly. Manganese can occur just as well in the olivine as in the pyroxenes, and so long as organic matter is not present in the soil water, it remains behind as manganese dioxide in the iron oxide. In the presence of organic matter the manganese dioxide is reduced, dissolved, and carried away. And last, but not least, the peridotites of this region at different places contain nickel, which, in its behaviour, lies between magnesium on the one side and manganese and iron on the other. Hence it dissolves somewhat in the soil water, but with much difficulty, so that much of the nickel is found left with the iron residue. It also occurs deeper, in cracks of the still incompletely weathered rocks. It is deposited with silicic acid as a pale to intensive green garnierite. Later this garnierite is leached through hydrolysis although the silicic acid is more rapidly carried away than the nickel oxide. So, going downward in the direction of the transportation by the soil moisture, we find iron with little nickel, iron oxide with more nickel, garnierite veins, magnesium hydrosilicates between blocks of half weathered rock, and magnesite in cracts and pockets of less leached rock.

With an eye upon the things of importance in mining, engineers have naturally sampled a number of prospecting pits and test borings. Analyses of these

samples throw light upon the course of the above described weathering process, but give only an approximate idea. From the mining standpoint, if a series of borings had gotten down through and below the ore, the analyses were suspended. Hence that in the quite extensive literature regarding these iron and nickel ores not a single series of analyses can be found which begins with the completely fresh rock and ends in the final residual product.

The only two peridotite analyses, which we have found[129] are of hand samples, collected by Abendanon (see Table 79). Alkalies and Ti appear to be entirely lacking, or at least were not determined, nor has either P or S been reported. The weathering profile is not considered and is necessarily precluded since large boulders in a river were sampled.

Table 79

ANALYSES OF PERIDOTITES

Named according to Gisolf[1] from Abendanon's collection	Harzburgite Sample 733	Lherzolite Sample 676
SiO_2	43.66 %	46.85 %
Al_2O_3	2.40 %	4.58 %
FeO	7.72 %	7.10 %
Fe_2O_3	0.53 %	0.19 %
CaO	trace	2.65 %
MgO	44.90 %	37.05 %
H_2O	0.45 %	0.65 %
MnO	0.15 %	0.10 %
Cr_2O_3	0.32 %	0.35 %
NiO	0.32 %	0.24 %
	100.45 %	99.76 %

1. W. F. Gisolf, Micr. onderz. gest. der Midden-Celebes-verz. Abendanon;--in E. C. Abendanon, Geol. en Georgr. doorkr. v. M., Celebes, III (Leiden, 1917), p. 1122.

Elsewhere[130] we find weathering profiles considered and described and, for that matter, analyzed for Fe, Ni, Cr, Mn, Al_1O_3, SiO_2, MgO, and H_2O (loss on ignition). But never does one find a complete series of analyses, which gives the complete composition for all layers down to and including, the fresh rock. Hence it is impossible to verify experimentally what has occurred in the course of the weathering process. They bored holes 17 m. deep, and even as deep as 22.5 m., but not one of these reached the parent rock (for that matter, that was of course not the purpose of the investigations which were merely to find out whether or not the mineral deposits could be profitably mined).

The profiles as such, even though incomplete, are sufficiently noteworthy to warrant saying something more about them. Dieckmann and Julius, for example, give the following (p. 33): On the surface lie "loose blocks" of laterite, blackish brown to black, on a "solid, hard crust" of dark reddish brown to purplish color, so-called layer ore (see Fig. 151, page 391). Below this lies "clay ore, mixed with hard pieces of ore," grading into "loam ore" without the fragments. According to Koomans, with increasing depth the color changes from brown, through yellowish brown toward yellow and finally light yellow. When this color is reached one has come to the so-called "weathering soil" lying on, or grading into the underlying "peridotite or serpentine."--A few of the bore holes seem to have been driven almost through the "weathering soil." For example, in Larona No. 8,[131] the SiO_2 content was up to almost 20% at 15 m. depth. The rock, however, has about twice as much SiO_2. This profile comes the nearest to being completely analyzed, the following elements having been determined: Fe,--Ni--SiO_2,--Al_2O_3--MnO_2 and also loss on ignition.[132] It is indeed a pity that figures for Al_2O_3 below 10.5 m., and for SiO_2 below 13.5 m. and for the other constituents below 14 m. depth have not been given. For the purposes of this book they would have been

129. E. C. Abendanon and S. J. Vermaes, Nota's betr. voork. v. nikkelen ijzerertsen Verbeek-geb. (Juli 1915), p. 33.

130. J. Koomans, De ijzerertsen v. Midden-Celebes. --In: Versl. Meded. Ind. Delfst. e/h Toep., 8 (1919), p. 90; J. W. H. Adam, Result. proefontg. Ni-ertsafz. Soroako, Jb. Mijnw. N. O. I. (1920), Verh. I, p. 224; Dieckmann and Julius, l. c., pp. 32-34, 46, plus bijlagen: schacht- profielen.

131. Reported by Rutten, l. c., p. 562.--Rutten considered it was obvious that the deeper weathering layers "gradually graded into serpentine," although not a single bore hole reached this serpentine.

132. Koomans, l. c., p. 96.

the most important data.

"The thickness of the layer of ore is very variable. Sometimes it amounts to 2 m. and more, sometimes it is entirely lacking."

In the general discussion (page 145) of the origin and development of the soil profile under the same sort of weathering conditions as those which prevail in the Verbeek mountains, mention was made of a surface crust, but this had been formed originally at some depth and afterwards exposed by erosion. Is that the same case here?--Dieckmann and Julius also describe a profile (p. 34) in which a soil layer, which they describe as "washed-on material," lies on the layer of ore, which they call "laterite." One does not, however, obtain the impression that this material was washed on as a result of the nature of the terrain. They further point out (p. 35) that "an unmistakable relation exists between the forming of the lakes and the laterization." But what that connection is, however, they do not definitely state. When, however, a little farther on (p. 37) they say: "During the submergence the peridotite rock in the depression was laterized, so that at the present day, now that the plain of Larona is dry, the surface is covered with a mantle of laterite," --then this is a statement very difficult to believe.

The following seems to me to be a more probable explanation: It is a fact that over great areas only a loam ore lies over the peridotite. This ore consists principally of iron oxyhydrates which are hot baked or cemented together. The laterite crust (the ore layer) occurs on the surface here and there.[133] It is evident near Larona and Batoe Besi, and more specifically in the lower parts of the ore fields, close to the Larona river (on the Bone-, Poetih, and Salo-Raja fields such an orographic relationship is less clear). Now it is only necessary to accept the theory that the river at that time had a little higher level, by which a ground water level was maintained at such a depth in the loam ore field on the slopes as to induce the formation of a concretionary iron ore layer immediately above it. That was the beginning and from that the layer could grow upwards, as has been described in Part I, pages 144-145. This laterite horizon does not develop in the water, but always just above the water.--Meanwhile, on the slopes loam ore washed off to places lower down. The profile never remained undisturbed. The river cut its bed deeper and, through erosion, the layer of ore was exposed at the surface.

Many have the idea that the hard layer of ore (laterite) is the result of material hardening at the surface. This idea has been discussed in Part I, page 152. In this connection two questions arise: (1)--if that idea were correct, why does not the loam ore where it lies on the surface always change into a hard ore layer? And should it then not be expected equally well on tops of knolls as on the slopes and on the lower and more nearly horizontal positions?--(2)--In the literature about other lands, Australia, the coast of Guinea, and other French colonies, one often comes across the opinion that for the formation of the hard laterite "crust" an intermittently dry climate is necessary. This is certainly not the case in the Verbeek Mts. Here the laterite horizon forms in a continuously wet, equatorial climate!

So that what thus far has been learned about the formation of laterite on the peridotites of Celebes, does not in any sense upset the general conceptions laid down in Part I of this work, but appears to establish them more firmly. But only more detailed local studies, many complete analyses and profile and terrain descriptions will, however, bring about a more satisfactory certainty. It is therefore imperative that one understands the whole history of the development of the profile even though certain stages in it be deduced in part from other data of the environment.

Now, something concerning the occurrence of the serpentine of the Eastern Celebes. One is many times inclined to the hypothesis that peridotites by themselves go over into serpentine, or at any rate we must believe that peridotite first must be covered on the outside with a layer of serpentine originating from it.[134] Serpentinization in general has been dealt with in

133. Compare the map 1b accompanying Dieckmann and Julius, l. c.

134. Compare footnote 131 on page 347.

Part I, pages 86, 87. Dieckmann and Julius[135] give some more definite particulars along this line. They say that "though the serpentinizing process is never lacking, the peridotites in this region are only slightly serpentinized. This conversion in any marked degree occurs only where these rocks have been covered over by younger sediments, or where sediments from clastic-peridotite material (peridotite conglomerates) exist."

In the first place where does one find serpentine?--Under the sediments; and from the above-referred-to literature it is clear that these sediments are predominantly, though not entirely, marine sediments. This makes it evident that at the time of the deposition the underlying peridotite surface was lying below the surface of the sea, and so exposed to the action of the sea water.

On the land lying exposed to the air, peridotites by no means must pass through the serpentinization process. Koolhoven[136] also states: "In many places peridotite is covered with eluvial, brownish yellow to brownish red weathering soils, and locally, especially on more or less horizontally lying parts of the terrain it may be covered with lateritic iron ore." There is not a word about serpentine or serpentinization. But farther on (pp. 145-146) he says: "Between the peridotite and the sediments which lie on it there is found a zone of at least ten to a few tens of meters of strongly compressed serpentine, originating from peridotite..... The conclusion is now obvious that we have to do with a shoving of the overlying mass of sediments over the peridotite substratum of mylonite formed out of the last-mentioned rock."

But is this conclusion really accurate?--water certainly does not combine with rock through shoving or sliding. Is it not more likely that first the exposed and then gradually lightly covered over peridotite was serpentinized in and by the sea water, and that much later, after the accumulation of sediments on the serpentine had become very thick, the sliding and the mylonization had occurred?--

Just previously it was very truly said: "Although serpentine frequently occurs in the peridotite region, though perhaps only locally, the above typical serpentine which has been strongly influenced by dynamic metamorphism is limited exclusively to the boundary between peridotite and sediment." There is thus serpentine which has not been so compressed and shoved. Yet this also while under the sea could have been lightly covered over by sediment, which, however, has been eroded off again. In either case there had been no occasion for shoving under pressure.[137]

Before leaving the subject of the basic eruptives, it may be remarked that as marginal facies, and also as small portions projecting up through the peridotite, rocks containing feldspar such as gabbro, norite, and diabase occur. In the publications referred to, dealing with this part of Celebes in particular, although it is never mentioned, it is almost certainly the case that the vegetation on soils which have been derived from these feldspar-containing rocks must be better than that on the soils in the regions where there is nothing but peridotite, for most probably in such soils a lack of K, Ca, and likely also of P will prevail. It is quite astonishing that on the so-called loam ore such a tolerably good forest vegetation can exist. Where solid layers of cemented iron oxide (laterite), however, lie at the surface or close under it, naturally nothing or almost nothing grows (see Fig. 151, page 391). This is because the plant roots cannot penetrate laterite, cannot form a root system, and so suffer from a lack of water. In contrast with this, on Mt. Moliowo, just west from Malili, where gabbro is the parent material, I have observed an extraordinarily luxuriant

135. L. c., p. 15.

136. L. c., p. 143.

137. Abendanon (Nota, etc., 1915, pp. 3-4) apparently starts out from the idea that peridotite by weathering always "first goes over into serpentine. Then follows transformation of the rhombic pyroxene to bastite....." All the peridotite varieties mentioned going over into the serpentine originating from it (to deviate?--E. C. J. M.)--Still not a word about such conditions as covering by sea water. But he does mention the more rapid weathering of olivine in comparison with pyroxene.

vegetation.

In each case all these basic to ultra-basic rocks produce reddish brown to deep red lixivia which, although they contain only small or moderate amounts of organic matter, are physically loose and pervious. If only a little of the marine sediment which had covered the rocks or which lies in the neighborhood remains, so that irrigation water comes from it, the chemical poverty may, in part, be compensated for.

* * * * *

A large proportion of the crystalline shales or schists, to the south of the Verbeek Mts. are "blackish gray, shiny or sparkling phyllites," consisting chiefly of fine quartz and mica particles. Coarser forms of these constituents are quartz mica shales and quartzites containing mica. From the standpoint of the soils formed from these rocks it is, indeed, a pity that amphibole, chlorite, and sericite schists are in the minority since the soils from such rocks are as a rule better.

Upon weathering, the quartz, naturally, is transformed into quartz powder and quartz sand. The mica swells up and disintegrates, afterwards forming clay minerals. The resulting soils are loam and clay, from light to heavy, sand-free to very sandy. Upon weathering, amphibolites with their hornblende leave sizeable quantities of iron oxyhydrate in the soil. This substance makes the soil looser and lighter. If the iron is less abundant the soil on the schists is pale. Then because of imperviousness there is very great opportunity for amphibian and subaqueous conditions to prevail in the soil in place of subaerial conditions, as described for the schist region of Central Celebes (pages 335-336). Conditions then prevail which are unfavorable for vegetation, such as a low pH.

* * * * *

In the north, as well as in the south, older and Tertiary marls and limestones are the parent materials of much calcareous red earth. The still younger, elevated coral limestone reefs in the south and on the islands are completely covered over with such a red earth.[138] On the red lixivium or eluvium there lies but little humous surface soil. The humus is so rapidly broken down that not much can accumulate. The teak forests on Moena offer a good example of such soil conditions. The climate with 3 dry months, as well as the soil, very much resembles that of the calcareous ridges running through northern Rembang and northern Soerabaja, on Java.

Although I was not fortunate enough to find evidence of it in the literature, the probability must be admitted that to the south of a line joining Kolaka and Kendari, on flat marl ridges, gray earth and <u>black earth</u> as a heavy, black cracking clay will be found.

* * * * *

And now just a few lines about the <u>allochthonous soil types</u> of southeastern Celebes. These soils, which have been formed exclusively from the silt coming from schists, marls, and limestones, will be principally light to very heavy kinds of loams and clays. Silt from the amphibolites has a beneficial physical effect, while a little silt from the "loam ore" has a still more intensive effect on the peridotites. Nevertheless a large part of the disperse iron hydroxide carried in through amphibian or subaqueous conditions will be fixed quite rapidly as iron concretions, such as hail ore and bean ore.

Where, however, as for example along flat banks of the lakes of the Verbeek Mts., fairly pure loam ore has collected we find a quite exceptional condition. The minimum amount of vegetation grows on it. Abendanon has already remarked how miserably a certain kind of grass grows along the banks of the lakes,

138. Cf. for example: J. A. van Beukering, Landb. k. schets Moena, "Landbouw," 9, 499. Here it is recorded: "a weathering soil reddish brown to chocolate brown, locally going over to a gray."

and that it is just about the only plant which can still hold out there. (See Fig. 135.) Below (Table 80) is an analysis of such a secondary sediment, along with other analyses of a primary (?) solid iron ore layer and loam ore:[139]

Table 80

	Chunks of solid iron ore Larona	Loam ore, clay ore Larona	Sedimentary ore, Lampea, close to the sea
SiO_2	2.04	1.53	5.18
TiO_2	---	0.15	---
Al_2O_3	5.04	7.45	12.91
Fe_2O_3	68.90	67.60	60.14
FeO	1.67	2.17	---
MnO	1.04	0.54	0.23
NiO	0.39	0.93	0.24
MgO	0.07	0.85	2.00
CaO	0.74	0.38	3.54
H_2O +	18.24	12.98	14.65
P_2O_5	0.094	0.011	0.160
S	0.096	0.196	0.10
Cr_2O_3	2.48	4.79	1.34
	100.80	CoO 0.09	---
		99.667	100.50

As may be seen, there is indeed some variability, but all three have the same general character. Because of the proximity of the sea the Lampea sample has a higher Ca and Mg content (presence of shells), as well as a greater amount of P. As the high Al content would suggest, it may perhaps be due to sediments from other rocks. Close to the lakes the figure does not rise above 7.5% Al_2O_3. But then one asks himself: from what mineral does 7.5% Al_2O_3 come?--Not from olivine: from the picotite then?--not very probably; from the pyroxene?--but if so, then presumably there must be an accompanying Na content. To be brief, the above analyses have been carried out only for metallurgical purposes, and not for petrographic or pedological studies.

Evaluation and Utilization of the Soils

Southeastern Celebes is another one of those parts of the Archipelago of which there is little to be said in particular or of importance regarding the utilization of the soil. Everywhere the population is sparse. Very few people live in the Verbeek Mts. as is also the case in the schist region behind and to the north of Kolaka, as well as in the limestone mountains. On the limestone in the south and on the islands, the red earth is poor. It gives but a scant yield of maize, and an even poorer one of rice, but still it is not unacceptable land. The needy population is, however, very backward in the utilization of this soil and is apparently content with very little. The use of various kinds of green manuring, farm yard manure, etc., would indeed make something more of this land. Even so we can hardly expect this region to develop into an important region for export crops.

Along the large Konaweh river there are, without doubt, really good alluvial loam soils, on which paddies should be

139. Analyses taken from Alex. L. Ter Braake, Versl. en Meded. betr. Ind. Delfst, en Toep, 15 (1923), p. 7, 8 and 18.

laid out. The low plain behind Kendari is now one of the best parts of the province.

From the agricultural point of view the Verbeek Mts. and adjacent regions and the whole peridotite tract can never amount to much. But from the point of view of mining there is certainly something to be expected, though it may not be until the distant future. On the basis of these mineral resources, iron and steel industries could be established both in the Archipelago, and in the neighboring countries.

Only where gabbros and other rocks containing feldspar break through the peridotite or in the neighborhood of the calcareous sediments (Kawala, Seseh, Kaporesa) can more fertile soils and a productive agriculture be expected.

In general schists are not a parent material which gives rise to first quality soils. However, this statement will not be true if the proportion of quartz be less and there is relatively more amphibole. But, as contrasted with peridotites and serpentines, schists are, however, always superior. Rutten[140] also confirms this when, in speaking about the contact of serpentine and gneiss on Manipa, he says: "As to how far the serpentine extends into the interior of the mainland can be approximately determined when the observer is at a little distance from the land. This is because of the sharp differentiation between the brown serpentine soil meagerly covered with vegetation and the mica schist soils which are densely forested with tropical rain forest."

Apart from that, on the peridotite and on the serpentine in the scant forest are still a number of dammar trees, which when time and opportunity permit, enable the thinly scattered population to earn some extra income.

If we now mention the coconuts occurring everywhere along the coast, then we have certainly not forgotten any important crop of southeastern Celebes.

* * * * *

Finally a few words about Moena and Boeton islands, since they are also a part of southeastern Celebes.

Everywhere in southern and eastern Moena the limestone is at the surface.[141] Consequently the people are obliged to plant their crops in holes in the karang, (limestone) which are filled up with a calcareous red earth, or terra rossa, in itself not infertile. In the west and northwest the limestone is covered over by a much thicker layer of this red earth. This region is, therefore, better suited to agriculture. Even some paddies are to be found on this soil. But the soil in the holes in the karang appears to be richer in humus and more fertile than that on the hilly land which is more to the north.

This hilly land is barren and dry. The vegetation consists of little else than thorny shrubs. Along the foot of the hills there lies a narrow strip of land which is covered by material which has been washed off from the hills. From the nature of its origin this strip is somewhat more fertile.

The low land in the west and north, marshy in the rainy time, does indeed have groups of small, fire resistant trees in the grass but it is still practically all one big cognonal (Imperata spp.). There are no rice paddies, and the few cocos which are growing there are unthrifty. At the present time much kapok is being planted on the better soils on Moena. In the interior and also toward the east there is still quite a good deal of teak forest. This might well be exploited.

Boeton, like Moena, is covered almost entirely by red earth which the natives generally kaiñgin. Since reasonably good harvests are obtained, the soil appears to be relatively fertile; yet not sufficiently productive to permit the land to be cropped every year. Groves of cocos are found everywhere. The soil is thus, indeed, better than that on Moena (compare the parent rocks as described on page 344).

6a. The Southern Toradja Lands

This relatively small part of Celebes is dealt with separately, since in

140. L. Rutten and W. Hotz, Geol. Exp. Ceram, enz. IXe Verslag, T. K. Ned. Aardr. Gen., 36 (1919), p. 569.
141. These details are for a large part taken from a survey made by Administrator Bouman Oct., '33.

various respects it is of such a distinct character. To the north, northeast, and northwest it is surrounded by regions which have already been treated under Section 3, Central Celebes (pages 330-341). To the south it adjoins the "Lake Region" which will be considered below under Section 6b, page 369 ff.

Soil-Forming Rocks

For the purpose of this book Reyzer[142] gave a provisionally adequate survey of the soil-forming rocks. It is mainly his scheme which will be followed here.

(a) In the east lie the Latimodjong mountains, a large part of which are made up of "all kinds of strongly schistose and metamorphic rocks." The following minerals occur: chlorite, sericite, epidote, quartz, plagioclase, amphibole, calcite, biotite, and still others. Besides all kinds of schists, however, there are silicious slates as well as gabbro and diorite. From this rich diversity of minerals an equally rich collection of weathering products can result.

(b) All around the Latimodjong Mts., but especially on the west side of them, a peculiar formation occurs which is called by miners copper slate (because a little copper is found in it). But the geologists, following Abendanon, prefer to call it the Maroro formation, after the Maroro river, in which river valley this formation occurs characteristically and on a large scale.

Reyzer describes the Maroro formation thus: "It is a peculiar suite of mostly red, but also purple, blue and green clay-stones, marls, or slates, with similarly colored, coarse as well as less coarse sandstones to conglomerates. There are also yellow colored sandstones and claystones." Reyzer believed that these rocks often contain globigerina and noted that "here and there they included limestone and calcareous sandstone layers."

"Toward the core of the Latimodjong Mts. the rocks become harder and exhibit schistosity; metamorphosis has also taken place. In general however the rocks are weak. The landscape to which they give rise is unmistakably characteristic (Fig. 136, page 354). As far as the eye can see the weakly rounded low hills of purplish red or also bluish green colored rocks extend. The rivers readily erode the soft rocks which are only weakly resistant. As a consequence the rivers are always filled with dirty reddish brown detritus."--(See Figure 95, page 254.)

I can entirely concur with the above description and I was also struck by the very widespread occurrence of the purple color, which does not change even after the disintegration of the claystones to earth and silt, nor after the transportation of the material and its ultimate deposition as alluvium. Also the extremely miserable vegetation on this formation hits one in the eye (Fig. 136). It is almost exclusively a thin grass.

After one of the repeatedly occurring landslides or earth falls exposes a sizeable broken face across this formation, no regular layering is visible. Rather, one is struck by the greatly broken up condition of this formation, which makes completely understandable Reyzer's comments: "Regarding the thickness of the formation we must fall back upon an estimate, because so far as observed, the copper-slate formation is so much broken up that it is not possible, on tectonic or petrographic grounds to construct a profile in any way probable..... Nor can definite stratigraphic levels be differentiated." In closing Reyzer says: "Regarding the age of the deposits referred to, opinions are as yet divided."

However, for the reader of this book it is of less importance to know whether the Maroro formation is of Cretaceous age, or that it belongs to the Lower or Middle Miocene, than to know what the genesis of the formation was and what has happened to it since. This latter is of particular importance in order to come to an opinion (it must be provisional) as to the value of this formation as a parent rock for soils. Is there anything to be said about this?--

According to the analysis of

142. J. Reyzer, Geol. aant. betr. zuid. Toradjalanden, Jb. Mijnw. N. O. I. (1918), Verh. I (1920), p. 154-209.--With bibliography of additional literature.

Photo by E. C. J. Mohr

Fig. 136. Toradja lands, Celebes. Maroro or copper-slate formation. Entirely deforested and pastured off by carabao (water buffalo). Severe erosion exposing the dirty purple-colored silt. (See pp. 353, 358, and Fig. 49.

Freusberg[143] a "(Globigerina-free) red claystone," collected northeast of Kalossi had the following composition.

SiO_2	71.60 %
Al_2O_3	8.94 %
Fe_2O_3	6.86 %
MgO	trace (small quantity)
CaO	0.60 %
Loss on ignition	11.50 %
Residue	(0.50)%
	100.00 %

Whether the loss on ignition included CO_2 as well as water, was not recorded, but this is not probable since it is stated that the claystone was "Globigerina free." If it be accepted that we are here dealing with a marine sediment, then it is obvious that according to Murray and Renard, it is a deep sea sediment, a so-called "red clay." It is true that not only does the color point in this direction, but also the fine grain (the formation consists predominantly of "claystones") as well as the relatively infrequent occurrence of Globigerinas, (in the form of layers of lime) while other fossils seem to be lacking. But the above recorded chemical composition differs considerably from the analyses of "red clay." In the analyses reported by Brazier and Renard[144] there is not a single one, (even not among those in which previously the fine constituents, less than 50 mu, were not washed away), which has more than 62% SiO_2 or more than 9% water. Moreover all of them have a little CO_2[145] (as $MgCO_3$) and quite important quantities of alkalies. In the analyses of Maroro claystones given above there is but 1/2 % available for alkalies, plus magnesia, plus whatever else may also be in it. Hence the Maroro claystone of which the analysis is given above is not directly comparable with either one sort or the other of deep sea sediment. It may

143. Quoted by Reyzer, l. c., p. 158.

144. Challenger-Exped., Murray and Renard: Deep-sea deposits (1891), pp. 425-435.

145. O. B. Böggild, Meeresgrundproben, Siboga-Exped. LXV (1916), records 13 samples of "Roter Ton," which however are not all red but bluish gray. Of them there are 7 with 0.4 to 23.9% $CaCO_3$, yet 6 are entirely free from lime. Unfortunately further chemical analyses are lacking.

however be, though we may not accept this to be the case, that since its elevation from the sea the sediment has been leached considerably by fresh water. This raises the question that if such a leaching did happen, did it occur only very recently? or had it already taken place during a much earlier period?

This Maroro formation presents still further difficulties. Reyzer recorded that in general "in this formation of colored rocks the coarse sandstones and the conglomerates appear to occupy the highest levels. For the most part they consist of fragments of red claystone." This last observation logically means that the sandstones and conglomerates must be younger than the claystones, yet that at the time of their formation red claystones must somewhere have occupied a place higher than the place of the deposition of the sand and gravel layers. Hence, between the time of the depositing of the deep sea clay, and of its being crowned with "coarse grained quartz sandstone with occasional inclusions of fragments of red claystone," various things must have happened.

The reader will perhaps ask why so much attention is given to this geological puzzle. The reason for that is: If marine sediments are exposed above sea level, in general they are in no sense poor parent material for the formation of soil, because when sediments accumulate in the sea they become saturated absorptively. Now the Maroro formation is merely called a marine sediment, nothing more. Hardening under pressure and during a long time has not very much altered its chemical composition. And now the chemical analysis indicates something different. The soil from the Maroro formation is also poor. An explanation of all this is urgently needed.

(c) To the west and northeast from the Southern Toradja Region occur many granites, including also quartz diorites and diorites. Of these rocks quartz, orthoclase, plagioclase, biotite and amphibole are the most important minerals.

(d) Around Mamasa in the west, on the eastern side of the granites, lies a strip of crystalline schists, among which gneiss, mica schist and quartz schist are quite the most important. Of these rocks the most important minerals are quartz and mica, as well as some feldspar.

(e) Between (a) and (b) in the east, and between (c) and (d) in the west, and extending still further northward up against the granites of West Central Celebes, and toward the south reaching to the gulf of Mander and the lower Lake region, is a large stretch which the geologists consider as a unit under the name of the Volcanic formation.

A number of effusive rocks and tuffs have contributed to build up this formation over apparently a very long period of time, from the Chalk into the Pliocene. During this time at different points the various eruptives have been thrown out or extruded, in part as lava which flowed out or as already previously congealed magma, in part as efflata of all sizes, which was scattered abroad over the land. As to the petrographic nature of the rocks, andesites predominate (see Fig. 144, page 365), as well as biotite-pyroxene-andesites, in addition amphibole and hypersthene andesites as well as basalts are found. As would be expected since they are so much older than most andesites of Java, many of these rocks contain veins of calcite and zeolites. According to the recognized terminology of Verbeek they could be placed under the "andesites with old habitus."

Especially toward the southwest, but also elsewhere, are found rocks richer in potassium such as trachyte (orthophyre). Above them leucite rocks are found, which also occur north from Rantepao, but especially farther south, to as far as Maros. These rocks will be dealt with later.

In composition the tuffs obviously correspond with the solid rocks to which they are genetically related. In part they have been deposited on the land, in part under the sea. It is only as exceptional cases that the marine deposits also possess more or less marine fossils. Moreover, from the beginning of their long existence--and for the oldest tuffs this obviously applies the strongest,--there have been two transforming factors acting upon tuffs: (1)--Tectonic forces have deformed them very much and moved them bodily (see Fig. 145, page 365). (2)--In so far as the tuffs were exposed to these forces from the beginning, weathering and erosion have acted on them. Much material was washed off and carried into the rivers and

Photo by E. C. J. Mohr

Fig. 137. Southern Toradja lands, Celebes. A detail of the liparite Baroepoe tuff exposed along the road from Rimbong, near Bilalang. (See pp. 363, 366.)

presumably into the sea. On the one hand, these materials which came from different sources and which were related to different kinds of rocks were mixed in the sea. On the other hand, according to the grain size, materials were sorted into layers of gravel and sand, of loam and clay. One must also realize that not only from the east but also from the north and the west, detritus in all sorts of forms had contributed to the mixed and sorted material, so that it is difficult to make out from where any one fragment, or any one grain might originally have come. Consequently, in travelling north from Rapang toward Enrekang, upon first entering the tuff region and coming across coarse sandstone or conglomerate for example, by far the greatest part of which consists of white silica fragments and red silicious iron fragments of the size of peas or beans, naturally the surprised observer wonders how this region can be characterized as one of volcanic tuffs. Yet, on the other hand, after travelling in the opposite direction, from the north toward the south, one realizes that no sharp boundary can be drawn between the localities with undoubtedly pure tuffs, with not even a single silica pebble of contamination, and those localities where quartz is the principal constituent. Hence it is entirely conceivable why the entire region has been mapped as a single geological whole.

Without doubt the youngest and as such also the purest tuff is what is known as the Baroepoe tuff. It is a loose and crumbly material, principally liparitic, with foamy, very pale pumice stone glass, in which are large quartz and feldspar crystals and some mica hornblende. The pumice stone weathers very easily, consequently the tuff easily falls a prey to erosion. If on the flat portions of the tuff a solid, clayey layer has developed, on which a good growth of vegetation has become established, obviously this offers more resistance to eroding water than does the fresh tuff. For this reason gullying is predominant, and in this region of

Table 81

RAINFALL DISTRIBUTION IN THE SOUTHERN TORADJA LANDS

Place	(Location)	Elevation above the sea in m.	Number of years of observa- tions	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Limboeng	North	400	11	152	182	242	306	330	314	282	183	71	45	102	210	264	2551	10	1
Rante Pao	North Central	700	22	187	462	395	520	523	364	230	167	123	131	205	297	459	3866	12	0
Makale	Central	775	17	143	226	234	344	365	215	129	92	70	76	111	189	222	2264	9	0
Kalossi	South Central	660	10	120	114	187	177	168	149	143	102	100	103	149	164	144	1700	12	0
Enrekang	South	50	23	162	219	241	264	277	225	179	117	65	65	142	172	238	2204	10	0
Mamasa	Northwest	1130	14	160	145	177	224	275	235	187	126	120	117	142	199	184	2130	12	0
Masawa	West	870	13	155	250	224	242	292	249	213	166	104	153	176	217	262	2548	12	0
Polewali	Southwest	3	14	98	153	171	190	255	234	146	136	96	100	179	200	199	2059	11	0
Paloppo	Northeast	at sea level	24	189	221	242	285	318	300	244	181	140	138	172	201	224	2665	12	0
Badjo	East	10	12	123	140	174	234	187	154	169	122	104	65	64	111	143	1667	10	0
Siwa	Southeast	at sea level	12	164	141	148	237	317	430	390	332	200	190	157	153	105	2800	12	0

abundant rainfall the erosion of deep canyons is a consequence (see Fig. 137, page 356).

(f) On the boundary between (b) and (d) like an almost straight wall, stands an enormous Old Tertiary limestone reef. In the north, the road between Rante Pao and Paloppo runs through it. In the south, half way from Rapang to Enrekang, it stands to the east of the road. Just south from Kalossi the reef appears to be doubled, for east of the principal reef, projecting through the claystone formation there rise enormous separate blocks. Also there are outliers along the west bank of the Sadang river, west from the main reef.

(g) A couple of small spots of Younger Tertiary formation here need only be mentioned.

Considering all the above facts together, we come to the conclusion that in the Southern Toradja Region a great diversity of rocks contributes to the formation of the soils. As to how, will be discussed below in subsequent sections.

Climate

For a moment leaving the periphery out of consideration, the central, higher portions of the southern Toradja Region lie at elevations between about 500 m. and a highest point in the Latimodjong Mts. of about 3,500 m. above sea level. Toward the south the elevations decrease to about 50 m. at Enrekang and down, still lower, to but a few meters above the sea at Rapang. The air temperature range thus lies between that of the tropical lowlands (about 26°C) and an average minimum of about 5°C. Since the greater portion of this part of Celebes is deforested, the soil temperature must be a good three degrees higher. On the map there are shown only small areas which are higher than 3,000 m. or even only just more than 2,500 m. Since the greatest proportion of the area lies between 500 and 1,500 m. elevation, the most of the region falls under the warm and temperate divisions.

As to the rainfall, this differs little from that of Central Celebes. Almost everywhere all months of the year are continuously humid with averages of more than 100 mm. rain. This is apparent from Table 81 above.

In considering the differences, which seem to be mainly due to the position of the stations with respect to the mountains and the directions in which the monsoons blow, it should not be forgotten that some differences occur because observations for all stations are not always for the same series of years, and that for many stations the observations are for only a relatively few years.

With such a distribution of the rainfall, only under exceptional conditions can the soil dry out. Practically speaking, always and everywhere the soil must remain wet or, at least, moist. Where the soil material is quite pervious, the weathering form which predominates is thus strong leaching with much air dissolved in the abundant water. Where the perviousness is slight, weathering would take place under slow, but continuous leaching with little air dissolved in the water.

Ways in Which Weathering Occurs and Resulting Soil Types

In the first place we should refer here to the comprehensive treatment by B. H. Paerels,[146] in his description of coffee culture in this region, and, in particular, call attention to his chapter I: Geographical description of the region (the southern Toradja Region) and chapter II: Climate and Soil. Supplementing my own observations which were made in the course of a relatively short journey through the region, besides a few side trips, Paerel's data have been drawn on heavily in preparing the following discussion.

In order to make for clarity in the treatment we will retain the subdivisions which were used when describing the soil-forming rocks.

(a) Even with a uniform temperature (thus at a certain elevation) and one type of rainfall and rainfall distribution, the great diversity in the Latimodjong rocks must, of course, give rise to all sorts of widely divergent soil types. Yet they all fall within the group of yellowish brown to red lixivia. On the basic rocks (gabbros) which, moreover, occupy the highest parts, Abendanon[147] noted "orange yellow quartz fragments" on "'flasser' gabbro, between the layers of which there frequently occur many large quartz lenses." But under forest on these rocks a loose, dark brown lixivium soil will occur with a certain content of humus, perhaps covered by a horizon of still more humous surface soil. Since this soil is very pervious, the chances for the formation of peat, even on flat places, are considered to be small. Even for bleaching, the conditions are unfavorable, so that normally everywhere on the Latimodjong Mts. a brown gabbro lixivium will almost certainly be found, and apparently will extend up to higher elevations than anywhere else in the Archipelago. The weathering stage is considered to be juvenile to virile. Doubtless because of the heavy rains in the high mountains and the inevitable erosion under such conditions, presumably the soil never develops as far as the more senile stages. Provided it is actually washed onto the land and deposited there, and not carried on off into the sea during transit, without any doubt the soil material which washes off from the mountains is of value for the lower lying lands.

Somewhat lower than the gabbros are the quartz diorites, followed by the schists, which become more acid until mica and quartz schists are found, although these last do not occupy any very large area. In the case of these last mentioned rocks there is an increasing residue of quartz gravel in the weathering soil. Broken silica fragments remain from the quartz veins which occur in all these rocks. After having been rolled and knocked about in the rivers these quartz fragments finally land in the plain as round, more or less flattened quartz pebbles, white if iron free, but dark red if containing iron. However, between the large chunks of silica and fragments of other rocks a great deal of quartz sand is ground up into fine to very fine quartz sand and quartz flour. As a consequence of this process much quartz is carried out from the colluvium to become a part of the alluvium.

Thus the autochthonous weathering soil consists of submicroscopic clay minerals, plus colloidal iron hydroxide and aluminum hydroxide (as little flakes of hydrargillite) plus some little, or even much quartz and mica mixed through the mass. The color of the principal lixivium layer will thus vary from brown via brownish yellow to pale beige, sometimes with an orange yellow tint. As the result of erosion these soil types supply quartz flour and mica fragments in varying proportions.

(b) Because metamorphically they are still the least altered, the red claystones of the Maroro formation weather the most simply, namely through taking up of additional water. If these are really deep sea deposits, then the clay minerals during their long journey to the bottom of the sea must have become absorptively saturated with Ca and probably also with Mg

146. B. H. Paerels, Agronom. beschr. v/d koffiecult. i/d Zuid. Toradjalanden, Meded. Afd. Landb. Buitenzorg, No. 11 (1927). [See also page 368 of this book.--R. L. P.]

147. E. C. Abendanon, Geol. en Geogr. doorkr. v. Celebes, I, p. 147.

and K ions, while much water of hydration would have been liberated. Now when this deposit is exposed freely to the air and is washed with rain water containing practically nothing but HCO_3 ions, these bases are leached out and replaced by hydrogen ions, while at the same time hydration occurs with the resulting swelling and disintegration of the rock. This may explain why Paerels[148] speaks of "the ease with which the rock is attacked" and "through which the whole weathers to a purplish red clay." However, I have not seen any place where "the more solid rock is covered by thick layers" of this purplish clay. Rather the contrary, which also seems very plausible, since because of the breaking up through swelling along the jointing planes the purple colored clay is washed off even before it is entirely destitute of absorbed Ca and as a consequence it is still neither heavy nor intensively cohesive. If however we study the analysis of the claystone (page 354) somewhat more closely we see that, even if all the Al_2O_3 is present as "clay," as kaolin, or even if the alumina exists as the minerals beiiellite or montmorillonite (see pages 77, 78) which are much richer in SiO_2 and water, there is always present an excess of silicic acid and water. Judging from its color the iron oxide should certainly be considered hematite.

If we consider further that the claystones here and there go over into sandstones, made up of coarser and finer quartz sand, then it is obvious that in the so-called claystones there must also be a certain amount of quartz silt. If this is considerable the claystones grade into the loamstones, which, as a consequence, weather rather to a red loam than to red clay. This assumption was actually confirmed in an examination of the water of the Mata Allo during a flood (Fig. 49, p. 182). From quiet places along the bank I was able to dip up in a glass some of the dirty purplish colored water. This suspension exhibited the same characteristic satiny light effect as flood waters coming from the marl regions of Central Java.[149]

When rain water runs down over it, loam of this sort, however, disintegrates more easily than clay. This is the cause of the serious washing of all slopes and the severe erosion of the landscape. After heavy rain along and on the road, on places where lime or calcareous sandstone layers occur in or between the purplish loamstones, one can see where those same peculiar coarse crumbs of a granular consistency have been accumulated, the same sort as are often seen in quantities in the marl regions. When not disturbed, almost clear water runs out of the mass of crumbs but if one steps onto the wet mass which has been washed together, the foot sinks suddenly into it and immediately strongly turbid red water runs out. Apparently the lime present had caused the loam to form coarse aggregates.

Where quartz sandstone occurs in the formation, the loam weathered from it, so far as it is considered a substrat for vegetation and source of plant food, may be thought of as being "diluted" by the quartz; on the other hand however the quartz sand makes the soil more solid and harder. Yet this does not reduce the erosion of the soil. On the contrary, only those parts of the formation which lie closer to the central ridge of the Latimodjong Mts. and have been exposed to more intensive pressure and hardening through metamorphosis offer relatively more resistance. Thus the lower parts of the landscape erode still more than the higher; hence, in the course of time, the land does not become flatter but always steeper, and rougher.

(c) In the granite region in the western part of the Southern Toradja country (see Fig. 138, page 360) are found the same kinds of soils as we have noted in the granite region of Central Celebes (see pages 334, 335). Where the rock is easily converted into a granular mass through the crumbling weathering of the feldspars, especially of the plagioclase, a residual sandy soil of a gray rusty color is found. **(Gr--(Wa to Ma).NN.ae.(1-2))**. If the weathering has progressed further, without erosion having washed away all or a part, there finally develops through the stage of a light brown, loose soil, especially

148. L. c., p. 16.
149. E. C. J. Mohr, Over het slibbezwaar, enz., Meded. Dept. Lb. Buitenzorg, No. 5 (1908).

Photo by E. C. Abendanon

Fig. 138. Southern Toradja Lands, Celebes. Mountains west from the Mamasa river. At the right the bare granite projects up through the thin soil cover. Foreground: fertile alluvium washed off from the mountains.

Photo by G. Gortmans

Fig. 139. A beautiful exposure of granite weathered to a bright red, sandy lixivium near the Todjamboe rest house, Mt. Poeang. Along the highway being built from Paloppo to Rantepao. Central Celebes.

at low elevations, a sandy red earth.[150] But this residual soil is then no loam, but a sandy clay. The mechanical analysis curve has two peaks, one in the region of the sand, between 5 mm. and 0.2 mm. (the quartz besides a few other still unweathered mineral grains), and the second peak in the clay region, the particles of which are smaller than 2 mu.

If this residual soil becomes a thin mud and is carried off by the flowing water, then at first the sand part becomes colluvium, that is, it piles up as sandbanks gradually migrating from the stream channel out over the land. On the contrary the clay part, the easily suspended sediment, can be deposited later as alluvial clay (see Fig. 138, page 360). But the Mamasa and Sadang rivers are quite long ones which also carry along cobble stones as well as suspended silt and sand. The former grind the sand finer and finer, so that more quartz flour is formed. And this is carried along with the suspended silt. The consequence is, then, that in the low plains loam and not clay is deposited from that suspended sediment.

Along the road between Rantepao and Paloppo, to the east of the watershed, may be seen beautiful profile exposures in the granite soil of Mt. Poeang. In 1931 near the Pasanggrahan Todjamboe one could observe all conceivable stages in the transition from completely fresh granite to completely weathered-out red earth (see Fig. 139, page 360).

(d) The residual soil on the crystalline schists, in so far as it has originated from gneiss, will, indeed, be much like that on the granites. But from the nature of the case where the rocks are mica and quartz schists, the soils must possess relatively more quartz. The higher the elevation and the more nearly flat the topography, the greater the opportunity for an increase in humus content of the soil and a resulting increase in acidity. These processes are enhanced by the moist climate which prevails there. Under a dark colored humous layer on the surface, a similar less humous layer lies below, in turn underlain by a leached-out pale layer of clayey white sand with white silica fragments and bleached mica crystals. On virgin land stands a forest, the trees of which have but modest requirements. Where the forest is cleared (in a certain sense by mistake) in order to make kaiñgins on the land, the peats and humus are washed away and consumed. All the finer material is washed out of the soil, and there is left behind, at least on the flatter pieces, pale sand and gravel. From steeper slopes also, that infertile material is washed toward the rivers, and rocks are freshly exposed which then begin to weather.

Meanwhile the rivers carry cobble stones out from this schist region as well as silica gravel and silica sand. Mica and feldspar, however, probably do not reach the lowland, since, before travelling that far, the mica has been ground up fine and the feldspar has been weathered away. Thus, in addition to this fine mica, clay and quartz flour are spread out as alluvium over the lowlands.

Now before taking up the volcanic formation, mentioned under (e) we must first say a few words about:--

(f) the great limestone reef. In spite of Paerels[151] stating that this "limestone weathers to a light red clay," it seems to me that the autochthonous soil on the limestone is definitely a dark brown. Just as elsewhere in continuously moist climates, this reef limestone also weathers into very fantastic shapes, so that frequently close beside quite deep pits filled with soil, pinnacles and blocks of rock project high above the soil (Fig. 140, page 362). The soil is loose and friable because the colloids in the weathering residue are saturated with lime, while, since the elevation lies between 400 and 1,000 m. there is some humus in the surface soil which causes a dark color. The proportion of the soil which eventually erodes and reaches the rivers is quantitatively considerably less than that of the detritus from the Maroro formation. But qualitatively, from the viewpoint of the vegetation, the material is much better. There is much lime in solution with clay and humus in suspension but no quartz sand.

(e) In the course of a long time the volcanic formation has developed

150. Formula as the previous one, but stage 4 in place of (1-2).

151. Paerels, l. c., p. 20.

Photo by G. G. Gortmans

Fig. 140. Southern Toradja lands, Celebes. Road over the limestone reef at Tondoklita. Everywhere the limestone sticks up through the shallow, dark brown, fertile soil which contains quite a good deal of humus; elevation 800 to 1,000 m. (See pp. 361, 368.)

Photo by E. C. Abendanon

Fig. 141. Southern Toradja lands, Celebes. Many landslides along the mountain trail in the Masoepoe river gorge, above Tandoeng, where it crosses Baroepoe tuff, with nowhere very much forest. Soil layer quite shallow; heavy erosion. (See p. 356.)

between the formation (a) to and including (f). But in the literal sense of the word there has been much reciprocal influence between this central formation and those which surround it. In the central field there were all kinds of ejecta forced out and erupted intermittently from different points. These ejecta were spread over the landscape and also, of course, over the surrounding mountains. As the mountains were higher in relation to the point of eruption there was a decreased amount of ejecta but an increased proportion of the finer sizes. From the earliest times, however, erosion has been operating continuously and effectively on all the exposed land and especially on the mountain slopes (see Figs. 141-143, pages 362 and 364). And as long as the granite mountains and the Latimodjong massif were higher than the volcanic region between them, the colluvia and alluvia in the valleys contained a mixture of the products of erosion from all the regions. On the eastern side the limestone reef acted as a barrier against this mixing, but where it stops, as to the north of Rantepao, and to the south of Kalossi, all the streams with their loads could flow through those places and where the speed of the streams was reduced, mixed deposits accumulated.

But meanwhile, such substances as could be altered were weathered further, so that in the colluvium there was a decrease of feldspar, augite, etc., during its movement. There was also an increase in the clay in the silt in suspension, so that the farther south (the main stream direction) one goes, the greater the dominance of the silica fragments in the gravel and the finer and more weathered are the alluvium, loam, and clay. Now and again a volcano erupted. Then suddenly a mass of ash came downward with the rivers and was spread out over other material. This differentiated the layers and gave rise to that inspiring complex of layers, the maximum thickness of which has been estimated at as much as 2,500 m. Geologically it is called a "tuff formation," though for a large part it is built up of material which can hardly be called tuff.

But in addition to the above, however, there is also differentiation to be noted within the volcanic formation itself. In the west, in the region of the drainage basin of the Mamasa river, the eruptions resulted in more lava than fragmental materials. Therefore more lava and less tuff occurs there. But in the north breccias predominate, that is to say that in that region most of the volcanic rocks have been broken up and the fragments again massed together with another arrangement. In that region the volcanic material presumably belongs to the oldest portion of the formation and has thus been most subjected to vertical pressure, folding, and lateral compression, which have taken place since the beginning of the accumulations of the sediments, perhaps as long ago as the upper Chalk period (see Fig. 144, page 365). In the central part of this region where the Baroepoe tuff is the youngest product of all, the principal material is tuff itself, that is, compacted efflata. Hence this central part must also have played the greatest part in the building up of the great quantity of material which had been moved toward the south. There the efflata and the weathering products resulting from it hardened afresh to tuffs.

In connection with this differentiation, the topographic situation (elevation and slope of the terrain), and the greater or smaller supply of other sorts of material have resulted in the various kinds of soil of the volcanic formation being of course very different, although there have been only small differences in the weathering forms.

From the beginning the liparitic Baroepoe tuff has been very pervious, so that the rain water always sank down through it very rapidly to great depths. As a consequence, there remains but little water in the upper layers of the soil, making it difficult for the forests to develop or for reforestation to be accomplished. Where, however, especially in relatively depressed spots, once the weathering of the pumice stone of the tuff had actively started, the perviousness of the surface soil became continually less and the water capacity greater, which is beneficial for the vegetation. As a consequence the deeper layers of the tuff remained drier and weathered less than the surface soil, while the increase of clay in the surface soil was at the same time a reason why more rain water ran off over

Photo by C. van de Koppel

Fig. 142. The Saädang river, to the south of Makale, between Palesan and Boeakajoe, Southern Toradja Lands, Celebes. Heavy surface erosion and gullying. Here and there some forest in the side ravines. A similar aspect as that of the valley of the Mata Allo. (See Fig. 49, page 182.)

Photo by C. van de Koppel

Fig. 143. The river Saädang below the canyon at Boeakajoe, Southern Toradja Lands. Celebes. In the foreground are tuffs which are more subject to surface erosion. In the distance are tuffs with heavy gully erosion.

Photo by C. van de Koppel

Fig. 144. Mappa village, Southern Toradja lands, Celebes. Bare tuff region. Wherever possible the Toradjans have laid out paddies. To the right, in the distance the andesitic Mt. Madjoka, on which coffee is raised. (See pp. 355, 363.)

Photo by E. C. J. Mohr

Fig. 145. Road from Rapang toward Enrekang, Southern Toradja Lands, Celebes. Folded layers of the older tuffs of the southern side of the great tuff complex. Tuff here already full of quartz sand, silicious iron, and silicious rock fragments. Soil hopelessly poor, the terrain pretty well deforested. In the distance a limestone reef. (See p. 355.)

the surface and into those depressions. The consequence is that deep gullies formed. The deeper these gullies, the less weathered and the looser was the tuff in which the gullies were formed. Severe gully erosion! But in view of the facts appearing in the discussion of erosion above in Part I we cannot be surprised at that. But we can hardly help being astonished at the depth of the canyon-like ravines which at times may be many hundreds of meters deep. (See Figs. 141-143.)

On Sumatra, around the Toba and Ranau lakes, and in the Padang Highlands, liparitic tuffs also occur but it appears, however, that the Baroepoe tuff has relatively more loose quartz crystals, and hence less pumice stone, which makes the soil very sandy. This, because of the diminished water capacity, is not so good for the vegetation. Perhaps this explains why on the Baroepoe tuff, as in the environs of Taroetoeng, a much less intensive agriculture exists. In the discussion of Sumatra we shall go into this question in more detail.

Where the Baroepoe tuff lies flatter and hence is not being eroded too rapidly, the weathering has progressed further and has formed bright light red sandy lixivium (**V.a.I.--Wa.(NN** to **nn).ae.(2-4)**) with more or less coarse quartz sand. In the regions near sea level the surface soil does not contain much humus. The higher the elevation however the cooler the climate, and the more humus that remains in the surface soil. These and other details about this soil are excellently described by Paerels.[152]

Where the parent materials were more basic cruptives, in the form of solid lava streams or conglomerates or tuffs pressed in between other rocks, the customary brown and brownish red soil types have been developed.[153] Where the natives have cut the forests, superficial erosion has carried away these brownish red eluvia, here and there exposing very beautiful spherical exfoliation weathering of compact old andesite[154] (Fig. 33). Many times the kernel of the sphere is still completely fresh, while the outermost shells, in which the structure of the rock is still distinctly recognizable, may be broken up and mixed together with only the fingers, when it becomes completely "weathered soil" at the end without any other of the original minerals than some magnetite. On Java this phenomena is seen much less often, for the simple reason that in general on that island the andesites and similar rocks are much younger.

* * * * *

Now as to the allochthonous soil types of the volcanic formation,--higher up in the mountains when they are derived from the basic members of the rock family, these are, of course, purer clay soils. And just as on Java the natives have not let a bit of such soils lie unutilized. The Toradja natives have made paddies on them, even high on the mountains (see Fig. 144, page 365). In spite of the fact that it is warmer and there is more sunshine below, the lower one goes, the less the productivity of the alluvia. This, however, is especially true of the smaller side valleys Along the very large rivers, such as the Sadang this does not apply, for these rivers carry sediment which is rich in both plant food and clay. But the farther south one goes the richer in white silica and red iron silica the gravel becomes. This was also the case in previous geologic times. From north to south the colluvia become continually poorer in plant food with more silicious gravel, and in the same way the alluvia of the short side valleys become continually richer in quartz resulting in less fertile loams. So it is comprehensible

152. Paerels, l. c., pp. 26-29.

153. Compare also: Abendanon, l. c., pp. 171 and 172.

154. Abendanon, and in imitation of him also Paerels, describing similar spherical exfoliation, speaks of tuffs with great bombs in them. It is possible that on other points there is agreement with this conception, but the continuous running connection from "bom" to "bom" through all these shells, makes upon me a still stronger impression, that all was originally one homogeneous rock mass. If need be, it may be accepted that the originally compact rock had first been broken through folding and pressure into coarse breccias, which then still later became weathered.

that in the higher lands around Rantepao and Makale much more fertile alluvia are found than in the lower hilly lands of Enrekang and Sidenreng (see Fig. 145, page 365). That in earlier times the natives living on these poorer soils were notorious because of their marauding and robbing incursions toward the north is, according to my opinion, not to be ascribed in the first instance to their nature as bandits, but because, in comparison with the regions to the north and also to the west, their lands were so much poorer. Especially east from Rapang there is an extraordinarily poor district with an extremely thin population. For that matter the highway traverses an endless grassy waste the whole distance between Rapang and Enrekang.

Around Pinrang is the Sawito plain, the extensive region where the sediments of the Sadang river have been deposited. Here is found a finer, more clayey alluvium, especially in so far as it has been deflocullated and precipitated under the influence of the sea water.

Evaluation and Utilization of the Soils

In the preceding sections various things have already been stated which really belong under this heading. This is again evidence of how closely evaluation and utilization of the soil are connected with the origin of the soil, with the parent rocks through the influences of the climate, and with the factors which are related to those influences. There is the additional fact that from a distant geological past to the present time the region here treated has been a focus for all kinds of movements of the earth's crust. This is also of great significance for what we must now consider. It is, of course, related to the fact that the land is so very rough that it is severely eroded. As a consequence, here really old, thick, senile soil types could never fully develop--as, for example, in Russia, or the U. S. A., or Brazil, or great regions in Africa. Before the soil becomes senile it is washed away. Thus the autochthonous soils are still relatively juvenile, and also as fertile as they can be. That however leaves something to be desired, for since the parent rocks are not rich in mineral nutrients, the soils developed from them are not very fertile. This is the case on the purplish red Maroro formation and even more so on a terrain formed as a colluvium of silica sand washed out from this formation. But on the volcanic formation the conditions are much better, although still not so excellent as those on Java, where the youngest eruptions invariably give rich, basic efflatas. In the Southern Toradja Region, however, the more basic eruptives belong to an earlier time, so that the efflatas ejected have disappeared from the scene, either by erosion or by weathering followed by erosion. In some cases they have been covered by younger material, and then have been compacted to hard tuffs and conglomerates. The younger Baroepoe tuff, presumably ejected by Mts. Karoca and Mariri and perhaps also from other craters, however, is much more acid and is more comparable with the liparitic tuffs of the Batak lands and the Ranau region of Sumatra. Agriculturally this ash is inferior to that of the young basic ash of Java and Bali. This is because of the lower water holding capacity, the slower weathering, and the lower content of the plant nutrients, Ca, Mg, and especially P.

Otherwise, the case is the same as elsewhere, namely, what the rain water carries to the rivers as sediment is always the best; hence the alluvial plains of the Southern Toradja Region, soil material of which originated from the volcanic region, as well as also from the limestone reef are, in general, fertile and in consequence are usually under cultivation, especially as paddies. Yet there is the following difference between these regions and the mountain paddy districts in West Java, where the farmers plant one crop of rice right after the other, without any resting period for the soil. Here in the Celebes, as we read in the "Report of the Agricultural Section for 1926" (p. 43): "In the plains of Rante Pao and Makale...excellent harvests are obtained. Much of the higher lying mountain paddy was seriously affected by "root rot," which apparently must be ascribed to the custom of the Toradja farmers of keeping the paddies flooded during the entire year." This root rot is also known on Java, particularly on the

very heavy loams or clay loams, with a large amount of extremely fine quartz flour, which are difficultly pervious for water, and which have a low air capacity. Root rot almost never occurs on soils of purely volcanic origin. This also appears to be the case here in the Toradja lands.

Meanwhile, how cautious we should be in the drawing and accepting of simple conclusions! For in a Report two years later we read,[155] "The bad stand of many paddies (in the Toradja lands), which originally was ascribed to holding the soil continuously under water can be entirely cured in the beginning by a suitable fertilization." Now it would not surprise me if additional experiences in the future would make the quotation read as follows: "The bad stand of many paddies which originally was ascribed exclusively to holding the soil continuously under water can for the greater part be cured in the beginning by a suitable fertilization."

As to the Rapang region, a few particulars about it will be included in the course of the treatment of the Lake Region.

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[It is greatly regretted that because Paerels' paper is unavailable we cannot here give a resumé of his[156] detailed and excellent soil description. Every Hollander who is interested in the details regarding the Southern Toradja Region, always first obtains that publication.--Translator.] Appended to his paper, Paerels[157] also states very clearly how the Toradja native uses his land. It may be briefly summarized as follows: most of the allochthonous lands, which are the best are occupied by paddies. Unirrigable terrain is planted to the usual food crops such as maize and tuberous crops, as well as "planted" with fish. The one commercial crop which produces an important export product is coffee.

It is notable that coffee, C. arabica, apparently grows independently of the nature of the parent rock or of the soils, for one finds plantings on very divergent rocks; such as--

1. on the old andesitic Sesean Boeloemanoek complex to the west of Rantepao;
2. on andesitic conglomerates and tuffs of the Sadoko complex, to the west of Makale;
3. on the liparitic Baroepoe tuff of the Karoewa and Mariri, to the west of the terrain mentioned under 1--above;
4. on similar sorts of tuff at Limboeng in the north;
5. on limestone in the Ambesoe complex, southwest of Makale;
6. on the same sort of limestone of the Doeli limestone reef, to the west of Kalossi;
7. on granite detritus, around Mamassa and more to the west as far as Arale;
8. on the core of the Latimodjong mountains, especially on gabbro detritus; but not on the Maroro formation; this is obviously too poor.

In contrast to this indifference to most rocks, the distribution of coffee is certainly governed by the elevation. Paerels gives the most favorable elevation as being between 800 and 1,600 m. and adds that the most excellent plantings lie above 1,000 m. At the same time there is also a pedological factor connected with this. The higher the elevation, the more organic matter the surface soil contains, and since humus makes up for certain shortcomings of the soil, good humus consequently exercises a predominating influence. Even the native of Toradja knows that; he works to retain and increase the humus in his soil.[158] The first he accomplishes by surrounding his coffee trees with piles of stone, so that in the course of time by erosion of the higher land a little terrace of richer, more humous surface soil forms around the tree. He thus applies the metho which, elsewhere in this book (pages 243,

155. Verslag over 1928 der Afd. Landb. v/h Dept. L. N. en H., p. 381.
156. Paerels, l. c., pp. 15-33.
157. Idem, l. c., pp. 36-39.
158. Paerels, l. c., p. 58. Compare his Figs. facing pages 48 and 64.

244), was recommended for the highlands of Flores. And he increases the humus by heaping up around his coffee shrubs weeds and grasses collected from the pastures. Even rotting plant remains are brought from the forest to be placed about his bushes. This is a notable example of pedological insight, which is completely lacking in the case of many other peoples, even Europeans, who consider themselves to be much superior in "culture" to the natives of Toradja.

Meanwhile it appears that there is need for devoting much care to the soil for even after he has fertilized his crops with what manure he can collect from his water buffalos and cattle, the Toradja coffee planter obtains only a modest harvest. The climate, which has only an incompletely dry monsoon, is not unfavorable to the coffee. It causes, however, continuous leaching of the soil.

It would be interesting to determine whether or not on the above-mentioned six types of parent rocks there are noticeable differences in the quality and yield of the coffee. These comparisons should be made under conditions of elevation, rainfall, and methods of cultivation which are in other respects equal. As yet that region is not far enough advanced for this question to be answered.

6b. South-Southwestern Celebes

Geographically this peninsula is cut off by a line through Polewali and Paloppo. But since the Latimodjong mountains have already been considered in the preceding section, we will discuss the region to the south of the line between Siwa and the mouth of the Sadang river. We may divide this region into three parts: (1) the low strip in the north; (2) the Lompobatang volcano and the region to the south which is under the influence of this mountain, thus to the south of the line between Makassar and Sindjai; and (3) the central strip between them.

This central strip is characterized by a rough mountainous region with complicated mountainous land along the whole western part, by the Bone Mts. in the east, while in the center is the wide valley, down which flows the Walanae river.

Several very low ridges divide the lower northwest into several plains. First is the Sadang plain. Southeast from it the Lake plain, and still farther southeast the Tjenrana plain extends to Palima. North from this last plain there is a district of low rolling to hilly land with some coastal plain.

Soil-Forming Rocks

These rocks may be found in the Western mountains and in those lying to the east of the Central portion, as well as in the south. The only part of the north which is of any importance at all in this connection is the northeastern hilly land.

Toward the south the moderately high Western Mts. spread out so that these join the Bone Mts. and the Bontorihoe Mts. to the north of Lompobatang. The impression is that that older massif had formerly extended much further south, but that in the south it has been covered over by the younger products of the volcano Lompobatang.

In the western mountains, as in the southern half of the Bone Mts., the principal rocks are tolerably basic eruptives, andesites and basalts. Apparently a large proportion of them originated in Old Tertiary time. Perhaps associated with them are still older rocks,--certainly there are also younger ones. More acid forms such as dacite and liparite seem to occur but seldom. They are found practically only in the east, at Cape Patiro. More important, however, are the rocks richer in alkalies such as phonolite and a number of other leucite-containing rocks. The Peak of Maros is the classic terrain of such rocks. Whoever wants to know more about this should read the account by Rutten[159] and the special treatment of the geology of Central Southwestern Celebes by Van't Hoen and Ziegler.[160] For analyses see Table 24, page 38. In addition a number of other samples from P. and F. Sarasin

159. L. M. R. Rutten, Voordr. Geol. Ned. O.-Indië (1927), p. 534-537.
160. C. W. A. P. 't Hoen and K. G. J. Ziegler, Versl. geol. en Mijnb. opspor. Z. W., Celebes, Jb. Mijnw. N. O. I. (1915), Verh. II, p. 235-334.

Photo by E. C. J. Mohr

Fig. 146. The Lake region, Celebes. Landscape north from Seengkang, in Wadjo; with Tempeh Lake in the distance. Allochthonous soils with much fine gravel of white silica and red iron silica, almost impenetrable by plant roots. Tree vegetation only along the water courses, elsewhere only very miserable grass. (See pp. 367, 380, 381.)

were analyzed by Hinden.[161] In the formation of soils these leucite rocks do not behave much differently from andesites and basalt. The kinds of soils developing from them will in the beginning be merely somewhat richer in calcium, but more regarding that later.

Besides those rocks, relatively young leucite rocks occur sporadically. In the western mountains there are two occurrences of older crystalline schists, a larger deposit lying east from Pangkadjene, and a smaller one southeast from Soempangbinangae. These rocks are made up of gneiss, as well as of a number of other schists, with the following minerals: quartz, mica, chlorite, epidote, glaucophane, hornblende, and garnet. Even marble occurs in these schists, at other times serpentine. Quartzitic sandstones of different ages are also found in the neighborhood. Eocene rocks and younger limestones occur over a much larger area with their characteristic landscape forms.

In the south, from the vicinity of Sindjai to close to the highway between Oedjonglamoeroe and Watampone in the north, the Bone Mts. consist of the previously mentioned old andesites with a much smaller proportion of other rocks. Thus far leucite rocks have been found at only a few points; schists never; old sandstones and limestones only along the western margin.

Farther on toward the north, however, the Bone Mts. continue as a lower, Neogene limestone mountain range, consisting of coral limestone which has developed into a beautiful example of karst topography. Besides these, around the coral limestone region more or less tuffaceous foraminiferal chalks also occur. These extend out both far to the south in the valley of the Walanaë, and also east from the Bone Mts., to close to Mara toward the south.--North from the Neogene chalks and marls, however, there is the low rounded sandstone country about Wadjo. Here and there these rocks might quite properly be called

161. C. Schmidt, Gesteine d. Pik van Maros: in P. and F. Sarasin, Entw. geogr. geol. Beschr. d. Insel Celebes (Wiesbaden, 1901).

gravelstones (see Fig. 146, page 370). According to Wichmann[162] these deposits had been formed from material resulting from transgression of the sea and wave erosion. They consist of "the rubbed up material of crystalline schists mixed with younger eruptive rocks." Wichmann believed then (1893) that the Latimodjong Mts. which he had seen only from a distance, were volcanic, and he did not realize that the material which formed these sandstones could have come from that direction. At present, now that we know much more about the above mentioned mountains, as well as more about the volcanic mountains lying not only to the east but more especially to the west from them, which we have already described under the Southern Toradja Region, we know that the source of the material of all these sandstones and gravelstones lying to the north, northeast, and east of the lakes, is in the crystalline schists of the Latimodjong Mts. and the other eruptive rocks in the southern Toradja Region. Thus we find a connection, not during years, but during long geological periods of time, between the always extensive deposits of all sorts of allochthonous, mixed sediments, which have already been discussed (pages 361-366).

If, finally, we consider the andesitic and basaltic effusives and efflatas from the Lompobatang volcano, with their conglomerates and tuffs, then we have included practically all the soil-forming rocks.

Climate

Because of moving farther from the equator and coming closer to those portions of the Archipelago which are strongly under the influence of the southeast trade winds, it is understandable that southwestern Celebes, especially toward the south, exhibits more differences of climate than Central Celebes. Moreover, the form and position of the land with respect to the east and west monsoons causes marked climatic differences. In this connection the rainfall figures (Table 82, page 372) are, indeed, very instructive.

The wet west monsoon has the most effect on the west coast where, after leaving Borneo it can blow over a large expanse of the Java sea, and then is forced up by the mountains lying in from the coast. Thus the rainfall is moderate at Pare Pare, heavy at Pangkadjene, and again weaker as the coast bends around more to the southeast. The least precipitation is in the eastern part of the low plain, at Faria, Seengkang and Palima in Wadja, although even there, more than enough rain falls to keep the soil wet.

In the beginning of the east monsoon, in May and June, heavy rain falls along the east coast and also more in the interior (Bikaroe). But later in September there are but few places in southwestern Celebes where more than 60 mm. falls. During this time the west coast to as far as Maros has at most 3 months, of an average rainfall under 60 mm., though the southwest coast has as many as 4 to 5 months of drought. The most southerly point Djeneponto with but 4 months above 100 mm. is the driest places in all of southwestern Celebes.

Hence, along the southwestern coast the soil dries out annually to a very marked degree. Consequently the conditions for plant growth closely resemble those of many places in the dry Smaller Soenda Islands and Southern New Guinea. Therefore it should cause no surprise to find between Takalar and Djeneponto on natural, unirrigated land the same savanna with palmyra palms (Borassus flabellifer Linn.) (see Fig. 147, page 373).

In the low plains in the north there are no definite months when it always rains heavily, but neither are there regular long continued droughts. Where the soil is quite flat and is not very pervious alluvium, it makes little difference whether 100 mm. or 500 to 700 mm. falls, for when more water falls than the soil can take up, the excess runs off over the surface. This is the case at Rappang, which has a total rainfall of 2,241 mm. and a continuously wet climate. Paria with 1,775 mm. is of course also wet. Provided the average rainfall figures over a series of years really did indicate the true condition from year to year, there could not occur in this low land an intensive and

162. A. Wichmann, Die Binnenseen von Celebes, Peterm. (Mitt., 1893), p. 281.

Table 82

RAINFALL AT CERTAIN STATIONS IN SOUTH SOUTHWEST CELEBES

Place	(Location)	Height above the sea in meters	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Number of humid (wet) months	Number of Arid (dry) months
Siwa	East Coast	at sea level	12	164	141	148	237	317	430	390	332	200	190	157	153	105	2800	12	0
Palima	"	"	12	120	93	133	174	289	347	286	218	97	84	105	137	121	2094	9	0
Watampone	"	20	25	153	141	167	233	308	327	358	200	108	76	115	149	165	2347	11	0
Mara	"	300	18	123	146	130	191	345	510	383	296	90	71	75	118	129	2484	9	0
Sindjai	"	at sea level	51	137	124	132	145	297	474	429	300	110	59	97	87	117	2370	9	1
Kadjang	"	8	49	118	160	159	193	295	466	388	227	70	36	66	86	151	2296	8	1
Pinrang	Lake Plain	12	21	109	210	175	188	276	291	166	149	57	78	143	172	183	2087	10	1
Rappang	"	28	22	112	170	183	199	292	291	212	165	103	113	165	166	182	2241	12	0
Paria	"	80	12	102	61	100	119	306	329	253	129	73	73	81	157	94	1775	7	0
Seengkang	"	12	24	131	92	110	114	193	244	220	133	81	45	87	150	115	1583	8	1
Pompanoea	"	15	24	129	103	138	145	237	259	222	147	82	51	88	127	125	1725	9	1
Watangsopeng	Central	120	25	122	180	146	162	238	244	205	117	53	54	101	141	167	1808	10	2
Oedjoenglamoeroe	"	400	16	152	160	149	165	200	210	226	167	88	54	74	149	175	1797	9	1
Tjamba	"	300	50	160	443	328	291	214	173	148	100	42	31	68	176	373	2387	9	2
Palataë	"	200	16	122	152	147	159	212	370	262	252	109	65	80	97	178	2084	9	0
Bikaroe	"	250	48	165	295	267	315	358	452	441	316	114	57	71	155	272	3113	10	1
Pare Pare	West Coast	at sea level	22	103	289	239	212	195	155	84	62	29	59	116	225	378	2043	8	2
Soempangbinangaë	"	"	22	123	438	410	327	204	160	85	58	26	36	101	235	566	2646	8	3
Segeri	"	3	49	120	672	509	451	237	169	117	71	30	35	106	318	658	3373	9	2
Pangkadjene	"	3	52	140	770	590	487	349	147	115	58	18	27	108	287	714	3561	9	3
Maros	"	5	19	121	727	525	415	207	123	77	52	12	25	100	229	641	3122	8	3
Makassar	Southwest Coast	at sea level	52	133	690	537	425	152	88	70	34	10	13	42	175	610	2847	6	4
Limboeng	"	10	17	89	701	451	283	99	60	41	13	6	19	63	192	554	2482	5	4
Takalar	"	at sea level	19	89	589	363	307	106	77	32	14	4	13	41	158	441	2144	6	5
Aloeë	"	3	48	94	453	378	247	115	97	66	32	11	11	42	145	384	1981	6	4
Djeneponto	"	at sea level	17	68	252	177	142	63	88	67	46	9	11	17	45	224	1144	4	5
Malakadji	South	750	17	141	455	358	352	283	219	136	61	30	23	60	235	415	2627	8	2
Bontaëng	"	at sea level	49	98	146	116	126	131	206	199	127	44	24	49	76	112	1356	8	3
Boeloekomba	"	"	16	95	105	93	114	154	260	193	125	26	19	47	49	91	1277	6	4

Photo by E. C. J. Mohr

Fig. 147. Southern Celebes. Between Aloeö and Djeneponto. In the lee of the east monsoon. Long dry season. Good "black earth" from volcanic tuffs and conglomerates on convex terrain, with a natural stand of palmyra palms (Borassus flabillifer). (See p. 377.)

deep drying out of the soil, such as is general along the southwestern coast. But this is an assumption which is not valid. This question has already been considered in discussing Halmahera (see page 310). This is, perhaps, one of the reasons why in southwestern Celebes, along the coastal plain from Makassar to Boeloekomba a continuous forest does not exist as natural vegetation, although according to the rainfall figures it ought to (see Fig. 149, page 380). However, there are also other reasons which will be discussed later.

Forms in Which Weathering Occurs and Resulting Soil Types

Apart from some trachytes, phonolite and bostonite which, judging from the limited area in which they occur, have had only a relatively small part in the formation of the soils, most of the rocks are predominantly basic igneous rocks with an FeO content which is usually between 5 and 8%. This indicates that the lixivium soil weathered from them doubtless still contains enough iron hydroxides for it to be quite pervious (**V.b.--(He to Ma)(NN to Nr).ae.(2-4)**). In only a few unimportant points does the elevation exceed 2,000 m. From the pedological standpoint the rocks are all quite old and only through erosion have some spots recently been exposed. Here, of course, the weathering stage is still juvenile. The general picture is thus of much brown and especially red lixivium on the Bone Mts. as well as on the Western Mts., and on the Lompobatang Mts. and their outliers.

The material which the rivers, because of the erosion, carry away from that region consists of red silt gradually becoming brown, magnetic iron sand, and (especially from the tuffs and conglomerates) rock gravel and stones. The cobblestones rolling along the river beds thoroughly grind up the gravel. Thus rivers flowing out from the tuff region seldom deposit completely weathered sand-free clay, but rather because of the content of powder from feldspars, augite, and hornblendes they deposit a more or less juvenile loam, though it may often be a heavy loam. Besides that, however, they often deposit small sand and gravel banks, which

are originally not farther along than the first or second weathering stage. The plain of Goa is a typical example of a heavy loam of this sort which, even yet in the east, close to the hills, possesses an astonishingly large content of weatherable constituents.

The rocks containing alkalies and alkalies plus $CaCO_3$ give rise to similar kinds of lixivia as do the andesites and basalts. Perhaps the trachytes relatively poor in iron give rise to a somewhat paler soil, in the beginning a pale yellowish brown, later more of a light red, but the character cannot differ much. The plagioclases and augites are almost always just about the same, though those rocks may be somewhat richer in alkalies, especially potassium. One should perhaps expect that the clay minerals of these lixvia should possess considerably more potassium in absorbed form than the lixivia from ordinary andesites and basalt. Yet this is not so probable as it appears at first sight, because the leucite, which at the first moment supplies the K, weathers much more rapidly than the feldspars, which must absorb the potassium. So it appears quite probable that even with the free silicic acid liberated at the same time, the potassium is to a considerable extent washed out because enough absorbent has not yet been developed. These questions are still however all a matter of speculation, for experimental data are not yet available.

The old, mostly Eogene limestones of the Western Mts. have been so incised along the top through unequal erosion and weathering that even on the newest topographic maps they are shown as "Impassable limestone terrain." There is thus good reason why apparently no one has yet made any observations relating to the soils on these rocks, let alone having recorded anything about them.

We must, therefore, be satisfied with the supposition that ultimately there will develop a soil, and it will have admixtures from the limestone (tuffaceous layers, intrusions, etc.), plus what was blown onto it (volcanic ash during the time when the Lompobatang volcano was still active; and additional dust, who knows from how far?). Doubtless the soil is concentrated in deep pockets, between which there tower the bare rocks without any soil. It may be expected that here, just as elsewhere, this nummulitic limestone is tolerably pervious, so that the soil is either a terra rossa, or in case the tuffaceous parent material is especially poor in iron, the resulting clay will be plastic, and dark brownish-black.

We find an entirely different picture in the Neogene terrain around Bone. The limestones from coral and the surrounding marls apparently disintegrate easier than the older, harder, Eocene limestone. Also the central limestone weathers into numberless little peaks which on Java would be called "Goenoeng Sariboe." The farther one goes toward the edge of this region, however, and farther into the long, flat Walanaë valley, the richer the marls become in clay and fine tuff material, and the more gentle are the slopes of the hills. The soil, which in the center, on the tuffaceous limestone, is still more reddish brown **(tK--Wa.NN.ae. (1-3).)**, goes more and more over into pale brownish yellow and flecked yellowish gray marl lixivium. **(M--He.nn.(ae to am). (1-3).)**. There is more fertile loam which, moved by erosion to some other place, is deposited as an equally pale ochreous colored loam or clay. If this soil material happens to be deposited under amphibian or even under subaqueous conditions, the iron becomes movable and the ground bleaches and becomes gray, as is the case in the low plain of Soppeng and in the low flat Tjenrana river valley. In such soils, iron concretions obviously must occur, and most likely as hail or bean ore. On the other, the western side of southwestern Celebes, throughout the flat coastal plain from Pangkadjene to close to Makassar are found more beautiful examples of ore of these kinds.

On the Makaraëng estate, a little to the south of Maros, there is known to be a deposit of ultimately utilizable iron ore. As early as 1906, through the then Assistant Inspector of Native Agriculture, de Savornin Lohman, I received samples from this deposit. In 1913 this ore was studied carefully from the economic standpoint, by 'T Hoen and Ziegler,[163] who wrote about it as follows: "In the plain unfortunately"

163. 'T Hoen and Ziegler, l. c., pp. 290-291.

(it does not appear to me that it is necessarily unfortunate--E. C. J. M.) "ordinarily in rice fields between lateritically weathered small hills of tuff" (which thus apparently have always remained above the ground water level--E. C. J. M.) "are found formations of limonite, which resemble bean iron ore deposits. The ore in its original form consists of a reddish brown mass of coarse hail-like limonite grains, caked together with clayey iron oxide constituents. Each grain in itself consists of a brown iron ore shell 1 to 2 mm. thick, surrounding either a dark brown powder, or a weak, sandy tuffaceous mass."

"The caked-together mass becomes disintegrated by flowing water (for example, by the paddy irrigation water, so that limonite grains which are spread everywhere through the dark gray soil of the paddy fields are worked loose and are washed out in a relatively pure state." (In 1906 there was sent to me a sample of such washed out grains, of the size of dun peas and brown beans, but their color was not reddish brown, rather dark chocolate brown to brownish black.) "Pieces are found which consist merely of enlarged limonite grains. The average size of these grains is about 3 mm."

To supplement this description a few words are quite necessary to give a clearer idea of the material. It seems very improbable that a relatively hard limonite shell should deposit itself upon and around a "brown powder" or around a "weak, sandy-tuffaceous mass." However, when we see on the very simple sketch map of 'T Hoen and Ziegler on page 291 of their paper that "limestone" is recorded everywhere in the "little tuff hills," then it may perhaps not be too hazardous to suppose that the original kernels of the bean-shaped limonite grains might have had a residual grain of limestone, or even a grain of sandy tuffaceous carbonate. In the course of a long time this lime would have become leached out, and perhaps in the space left some earthy iron hydroxide was precipitated. It is however also possible that as a starting point hard lime concretions had existed in the soil, from which similarly in a later stage the precipitated calcium carbonate had subsequently been dissolved and carried away by water poor in lime.

It should cause no surprise that with the considerable dilution, which occurs as a result of the action of the circulating water from the heavy west monsoon rains, the "caked together masses" in the paddy soil are dispersed. At such times the clay obviously becomes hydrated to the maximum and then is weak, added to which is the trampling of men and of water buffalos. This mechanical disintegration accelerates the effects still more.

'T Hoen and Ziegler also give three analyses which were made in the laboratory of the Mining Bureau (see Table 33, page 376). But without more data than these analyses give, it is unfortunately not possible to give an idea of the mineral composition. What does "insoluble" mean?--Presumably the sample was heated with strong hydrochloric acid, but strong sulfuric acid or potassium bisulfate may have been used.--And has the silicic acid which has been determined resulted from the solution of these minerals analyzed? or is it from that portion of the sample not attacked by the solvent?--In what form did the Al_2O_3 occur in the original preparation?--With what substances should the combined water be thought of as having been combined?--In short, a fractional analysis according to Van Bemmelen, would perhaps have given a better idea of the real nature of the sample. At present, we must be satisfied with the presumption that the material is from about a half to three-quarters Fe_2O_3. Another point of importance is the fixing of about 1/2 % of P_2O_5 in these iron concretions, which means that the P so fixed must be considered as practically unavailable for the vegetation.

In conclusion allow me to quote the following from 'T Hoen and Ziegler (p. 291): "Such bean iron ore deposits, brown iron ore concretions" (does it seem that the analyses show enough combined water to be present?--E. C. J. M.) "in lateritic soils are frequently to be found in low regions of red clay which are surrounded by limestone on the west coast (Maros, Pangkadjene, Podo in Barroe), also on the Bone coast (at Teko)." This is entirely in agreement with what has already been stated above in more general terms (pages [illegible], 189, and 374). However the qualification that the surroundings should be of limestone may presumably be omitted.

Table 83

BEAN IRON ORE FROM MAKARAËNG (MAROS)

Number	I	II	III
Place Collected	In a Paddy, just above a pasture field	In a Paddy, southeast from No. 1	In a Paddy, to the south of estate house from a bore hole 1.5 m. deep
Nature of the sample:	Compact bean ore of limonite grains caked together with laterite	Same as No. 1	Clay with loose iron ore concretions; analyzed after the washing out of 17.28% clay
"Insoluble"	17.15	17.44	8.72
of which SiO_2	11.72	12.28	8.20
Fe_2O_3	51.35	54.78	74.88
Al_2O_3	17.01	15.96	3.86
Cr_2O_3	0.08	0.06	0.04
Mn_2O_3	trace	trace	trace
P_2O_5	0.54	0.34	0.49
H_2O + 100°	9.61	8.58	9.47
H_2O − 100°	4.22	2.67	2.28
Insoluble, No SiO_2	5.43	5.16	0.52
Total.............	99.96	99.83	99.74

In their "Soil Researches of the Regions outside of Java"[164] to which we have already repeatedly referred, C. H. Van Harreveld-Lako and A. Arrhenius recorded soil types with very many iron concretions from the environs of Boeloekomba, and for that matter also from the south foot of Mt. Lompobatang, where, in so far as is known there is no limestone at all. In general this paper is of great significance in this connection, since, in the description of a number of parts of the plain of southwestern Celebes, the authors record details which admirably illustrate the general conceptions we are presenting in this book. For example, with respect to the plain of Goa they state that:[165] "In the southernmost part of the plain, in the neighborhood of the Sanrabone river, and especially along its southern bank the soil becomes heavier. Here is found heavy brown clay.... farther southward this becomes still heavier....and in the neighborhood of Takalar the soil is almost black..... Under the heavy clay, at a depth of one to 1.5 m., the soil is coarse and sandy and contains weak shells and half-consumed residues of an old swamp forest....."

The farther south one goes, the darker becomes the color of the increasingly heavier soil ranging from gray through brown to black. It is possible that this black soil at Takalar is a brackish water alluvium and was deposited in a coastal swamp. But it is also possible that the color is connected with the relatively dry climate, which becomes still drier toward the south and southeast (cf. page 372). Beyond the Goa plain, between Takalar and Djeneponto there is a hilly terrain which, in spite of the fact that it consists largely of eruptive rocks, impresses one as being an outlier of the Western mountains toward the south, rather than belonging to the Lompobatang complex. Not only the trend of these Western mountains which, in general, seems to be north and south, points toward this, but also the abundant occurrence in them of zeolitic veins and cavity fillings. In addition there is often so much chalk that the

164. Meded. Proefst. Java-Suiker-Ind., No. 18 (1927); Arch. S. Ind. N. I., III (1927), pp. 709-828. In that see especially pp. 801-802.

165. L. c., p. 795.

rocks may be called marly tuffs and conglomerates. Even tuffaceous marls and well stratified, calcareous marls have been seen. But the soils on them are not brighter red, as at Maros, but rather are darker, a gray brown. The richer in calcium the tuff marls are, however, the blacker the soil which lies on them. Van Harreveld-Lako and Arrhenius refer thus to these soils:[166] "On and between the hills the soil is a very heavy, black clay, sometimes gray to almost white; usually the arable layer is deep." Especially all of the rolling country (see Fig. 147, page 373), with many flat portions, to the south of the highway between Tamanroja, Balang and Djeneponto has this black soil (mT or tM--He.nvv.am.3.) which is so common on the Smaller Soenda Islands, while on Celebes at Limboto and Loewoek it is a curiosity. With the smallest annual rainfall of Southern Celebes, Djeneponto has consequently the longest and the most severe dry monsoon. On marls as the subsoil, I have observed a black soil 60 cm. thick at most. While on purer limestone where the soil was very thin, less than 30 cm., it was a dark brownish red. But even here if the soil was thicker it was likewise black. All of this black earth was conspicuously loose and crumbly. One wonders if there is not at times a considerable amount of wind erosion during the fierce southeast monsoon. Can this be the reason why there is so little soil on the marls and limestones?--If that is the case a great deal of the weathered material from these low hills must be carried away by the southeast wind toward the Goa plain, and since the surface soil was always dried out, that process must certainly have greatly enriched this plain.

Eastward from Djeneponto the marly tuffs are quite quickly replaced by hills and ridges of eruptive material. These hills also are covered by black earth on to about as far as Togo, although farther on, in the direction of Bontaëng, the soil is exclusively a reddish brown lixivium. Apparently the effect of the pure Lompobatang material is to give greater perviousness which brings about intermittent or continuous leaching. Here "around the corner" the total rainfall is also still small, yet Bontaëng has a much shorter dry season than Djeneponto and twice as many months with the rainfall above 100 mm.

In the meantime the question cannot be answered definitely as to whether or not the occurrence of the black earth is related to a definite parent material rather than to a definite climate. It appears to me that it is most probably not a question of "either....or," but rather of "both....and." The climate is responsible for the conditions of water movement (N.r--or n.vv--). The parent material is marly, which might well bring about an alkaline reaction, a pH higher than 7. The location of the soil in low places with only weak convexities of the terrain means that rain water once taken up does not either run off rapidly nor does it percolate down through. Instead the water is held tightly until it is again evaporated.

In addition, the soil of the western coastal plain (see Figs. 27 and 148) shows all kinds of interesting peculiarities. One should be inclined to suppose that black clay occurred there extensively. This is, however, very far from being the actual case. Of all the samples described at that time by Van Harreveld-Lako and Arrhenius[167] there is only one (No. 2932), which might be called heavy. And even this one is a subsoil from at least 1 m. below the surface. All the rest of the samples are loams, ranging all the way from heavy loams to slightly loamy sand.

The reasons for such textures may be surmised. The rivers coming out of the mountainous land, especially those which flow out from the region of old schists and sandstones lying behind Pangkadjene, carry out not only colloidal clay but also much quartz powder and quartz sand. As soon as these streams reach the plain the coarser material is naturally the first to be deposited, while the finer is deposited farther on, more to the west, and the colloidal clay settles out especially along the coast, where the salt sea water causes the clay to flocculate. Hence, east of the highway, more of the soils are loams and sandy loams while to the west is found the heavy clay. Naturally, strips

166. L. c., p. 803.
167. L. c., pp. 795-799.

Photo by H. J. Lam

Fig. 148. Southern Celebes. View from a limestone mountain which stands out by itself on the west coast, over the plain of abrasion and the limestone mountains lying behind it to the Peak of Maros (volcanic, leucite rocks). (Cf. Fig. 27, p. 158.)

of sand cross both localities from east to west.

Here east of the highway the natives have laid out a large proportion of their paddies. Hence, samples collected from the localities where paddy is grown are especially apt to have a loam texture, as was the case with Van Harreveld-Lako and Arrhenius's samples.

But there must be a reason why the natives prefer these loam soils to the heavy clays--these lighter soils must be more fertile. Quartz powder and quartz sand do not bring much glory to a soil! Hence we must conclude that these soils must also contain much fine tuff material; as well as, of course, some chalk from the limestones.

A factor not to be underestimated is presumably also the fact that the parent material (cf. analyses of the leucite rocks, Table 24, p. 38) is relatively rich in phosphorus and that the rocks are also quite rich in iron. If the detritus becomes weathered under amphibian or subaqueous conditions then there is every chance that iron phosphate will be formed, i.e. Fe concretions containing P. In such a state the P which is precipitated is only difficultly, if at all, available for the vegetation. However if the soil is a lighter loam, then the fixation does not proceed so far. For example let us compare the following analyses (Table 84, page 379).[168]

Although the contrary might well be expected, the heavy clay here appears to be the least rich in P.

* * * * *

When discussing the climate (page 371) it was stated that in spite of the fact that over many years they have averages of only a few "dry" months, the low flat parts of central and northern South Western Celebes may nevertheless suffer a considerable drought during a series of years, after which one wet east monsoon with heavy showers suddenly brings the

168. Van Harreveld-Lako and Arrhenius, l. c., p. 800.

Table 84

No.	Horizon	Description and Location	P_2O_5 HCl Soluble	P_2O_5 Citric Soluble
2933	Surface soil	Gray, light loam. At Baroboro, West from Maros	0.145%	0.022%
2932	Subsoil	Dark gray heavy clay. At Pakali, east from Maros	0.133%	0.007%
2936	Surface	Yellowish gray, light silt loam. West from Amarang, and south from Maros	0.192%	0.011%

rainfall back up to the average again. For example, if we go into the rainfall figures year by year during 15 years (1916-1930) for such places as Pinrang, Rappang, Seengkang, Pompanoea, Western Soppeng and Oedjoenglamoeroe then it appears that 8 of the 15 years show a considerable drought, with 3.5 to 5 dry months, while 5 years at the places mentioned show 2.5 - 2.5 - 3.5 - 3 - 3 and 2.5 months with less than 60 mm. precipitation. When calculated over a number of years, however, as given in the table, the average rainfall per month, such as are shown there, indicates only 1 - 0 - 1 - 1 - 2 and 1 "dry" months. Hence, it is obvious that such monthly averages are still a long way from being an accurate representation of the climate, at least as to the occurrence of marked dry periods. In place of the method of presentation being used in this book, it would be better to go into the duration of the dry period, or periods, for each year and to statistically work out their length. However, I have had neither the time nor the opportunity to do this. As long ago as 1916 I had W. Van Bemmelen[169] draw a climatic map of Java. This map gives the average number of rainy days during the four driest months of the year. Ten years later, at the request of the Experiment Station for the Java Sugar Industry, this map was revised and supplemented with more recent data, but it was not again printed, although a map of this kind is of marked help in a study not only of the vegetation but also of the soil. Without doubt such a map for the whole Archipelago would bring to light big surprises. Meanwhile, if the map referred to be compared with Fig. 6, by and large the agreement is indeed very close.

To be brief--in the Lake Region and in the low lands along the lower course of the Walanaë river many places have more years with a long drought than years without. This indicates that where the soil material has a tendency in that direction, and where the topography is also favorable, there is an opportunity for the formation of black earth. Indeed black earth, speckled with iron and lime concretions has, for example, been reported[170] in the plain of Bengo, northeast of Oedjonglamoeroe, along the road to Watampone; and also from near the Leworang river, north from Watangsoppeng, though here it is true the profile is without lime concretions. Also at Amparita the soil is a heavy, black strongly cracking clay, with an astonishingly high phosphorus content (see Fig. 149, page 380).

Beside the black earth referred to **(tM--He.nvv.am.3.)**, which in these parts of southwestern Celebes originates from tuffaceous marls or from calcareous sediments which perhaps never have been hardened to solid rocks, it is possible that black earth may be found in and around the soils of the large lakes. These lakes in different years, as well as during the different seasons of a single year, can have very divergent water levels--high and low water levels may differ as much as 7 m. and consequently great differences in extent. It

169. W. van Bemmelen, in: Verz. Verh. aang. grond N. I., uitgeg. n. a. v. Bodemcongres Djocja 1916 (1920), p. 64.

170. Cf.: Van Harreveld-Lako and Arrhenius, l. c., pp. 804-805 and 810-811.

Photo by E. C. J. Mohr

Fig. 149. The Lake region. Southern Celebes. Panorama looking toward the south over vast grass plains, to the west of the highway between Rapang and Watangsoppeng. In the distance the Western Mountains. Soil here somewhat better than to the east of the lakes. (See pp. 379, 382.)

is conceivable that under these circumstances in the Lake Region there will be a range of conditions from subaerial weathering on the places which are never overflowed, through all forms of amphibian weathering, to the subaqueous weathering where the soil material always remains under water. Thus there may be points with subaqueously formed black earth as a surface soil overlying a subsoil bleached grayish blue or bluish white (al--He.(nn to ns).aq.(1-3).). If the Lake Region were a zone with a continuous surplus of rain above the amount evaporated, then we should expect to find just as many leached out and poor soil forms as, for example, occur in New Guinea to the north of the Lower Digoel. However, here in the Lake Region from time to time long continued drought periods occur. Therefore, at such times a concentration of all sorts of dissolved constituents must take place. In other words, an enrichment of the soil occurs. If it rains after such a period of drying out then, in addition to silt, the rivers bring on fresh water, or more correctly, weathering extracts from their drainage basins. If the Walanaë or the Leworang river, which come from the south or southwest, is in flood, then it may be accepted that this indicates that the soils of the lowlands are being enriched. But if the Bila river which comes down from the north is in flood, then it is, indeed, very problematical whether or not that is any benefit for the lowlands. This is because the drainage basin of this river is far from fertile, and the hilly land to the west of it is certainly very poor (see pages 356, 359, 361, 366). In general, however, according to experience in rice cultivation the soils of the Lake Region are in no sense poor. They are fairly light loams, with a considerable water movement so that the vegetation can just as well draw its nutrients from a much diluted nutrient liquid, while on other soils it may draw its nutrients from soil moisture of higher concentration.

But immediately outside of the

region of adequate soil moisture, such as the rolling lands, just to the north of the lowest lake soils, as also in the hills of Wadjo to the east of this region, almost no vegetation can grow (see Fig. 146). Occasionally all of these unfavorable conditions prevail at one place, for example along the road which runs east from Pankadjene (south from Rappang). Here is a soil composed of small silica fragments, white quartz and bits of purplish red iron silicate. In itself this soil is extremely poor in plant nutrients; moreover, the soil is hard, so that the roots do not penetrate it readily. Besides, most of the rainwater runs off rapidly from it so that the few plant roots, none of which penetrate deeply, cannot find any water. No wonder that the vegetation is a desolate picture of want, and only in the little ravines can be found occasional groups of trees (see Figs. 146, 149).

Evaluation and Utilization of the Soils

If the reader has now acquainted himself with the preceding paragraphs, he will easily realize that the people of Southwestern Celebes have concentrated by far the greatest part of their attention, work, and settlements on the lowland, the sedimentary, allochthonous soils. Good, irrigable plains are to be found. There cultivated crops can find water or can be supplied with it by man, and water is the first essential for plant growth.

In Southwestern Celebes mountain plantation crops play really no part. This is not to say that on the hills and the mountains there is absolutely nothing cultivated. But even on the slopes of the old volcano, Mt. Lompobatang, what is cultivated is of very subordinate importance, hardly more than some tuberous plants, some cocos, and a few fruit trees in and around the villages which are usually located just on the edge of, or in the vicinity of larger or smaller plains. It is true that the reddish brown lixivium is physicially not bad, though it is not juvenile enough, being in approximately the third stage, hence quite senile. And since want has not driven the people to the mountains they have remained in the lowlands which offers more possibility of existence. For the Celebes, the Southwestern part is quite thickly populated,[171] but it is still a long ways from being as dense as the population of Java. The Census of 1930 gave the following population densities:

Subdivision	Persons per km.^{2}	
Makassar...	About 130	About 114 persons if Makassar town be excluded
Bontaëng...	" 85	
Bone.......	" 75	
Pare-Pare..	" 58	

These figures do not tell us much. A further subdivision into different topographic and soil regions is necessary to give a better idea of conditions. Take the Bone subdivision for example:[172] In Northern Bone, which has much lowland, there are about 160 persons per km.^{2}, while the lowland and low chalk mountains of Central Bone have about 93 persons per km.^{2}, and in southern Bone which for the greater part is mountainous and is covered with senile red lixivium there are but about 40 persons per km.^{2}.

There is no doubt at all that a closer analysis of different subdivisions would bring to light still more astonishing figures showing the connection between the nature of the soil and the density of the population. Such figures would also permit interesting comparisons with the other islands of the Archipelago.

Now as to the soils of the lowlands. From the Annual reports of the Agricultural Extension Service 1923-1929 (no subsequent ones have appeared), the general conclusion can be drawn that soils rich in phosphorus are found only in the west, that is, in the Sawito plain, and north from the mouth of the Sadang river.

171. See the small map accompanying the Reconnaissance map of Celebes of the Topographic Service, 1: 1,250,000 (of 1918).

172. M. van Rhijn, Mem. v. Overg. Febr. (1931), (Nota v. Toel.).

Also, southwest from lake Sidenreng, around Maros and here and there in the Goa plain, to as far as the vicinity of Takalar. On the contrary, the east exhibits a deficiency of phosphorus: Bontaeng, all of Bone, Wadjo and Sidenreng. When it is appreciated that the phosphorus content of the chalks of the mountains is all very moderate and the andesites are not rich in P, while the P content of the leucite rocks in the west is definitely higher, the explanation of the observed facts is clear. It is also possible that subsequent rock analyses will show that the older andesites in the west are richer in P than those of the Bone Mts. in the east.

There are marls in the North Bone Mts. as there are in the Wadjo Hills. The allochthonous soils derived from these formations presumably also contain relatively more lime. May it not be that this is an explanation of the fact observed in fertilizer experiments, namely, that at several places in Central and Northern Bone, in Wadjo and in Soppeng there is such a striking lack of nitrogen? In the case of paddy cultivation, however, the irrigation water can compensate considerably for an otherwise poor soil, providing it is adequately rich and the soil possesses sufficient colloids to absorptively hold the plant foods. But the following report[173] indicates that something else is wrong with these soils:

"It was remarkable that in an orienting experiment in Rappang on the poorest of all the sandy lands the different fertilizers as a whole showed no effects. It would appear from the research that these lands are presumably also deficient in potassium and calcium." That little word "also" may presumably be interpreted as implying that a deficiency of phosphorus had already been established. Farther on we read: "In an orienting experiment on the effects of fertilizers on the very sandy lands derived from the Masamba granite" (see page 338) "the fertilizers also failed to give any results." Here there is certainly no lack of water, though there was once a drought in the Rappang region. These two experiments thus very closely resemble the so-called sand cultures to which is supplied a nutrient liquid, containing several plant nutrient elements but lacking one or more of the important substances which as a rule are present in a loam or a clay. Without further investigation it is impossible to say what that something is, but nevertheless speaking in general terms a practical application can be made of the phenomenon in Southwestern Celebes. In the laying out of irrigation works, the fact must be taken into consideration that there are places where even with technically good irrigation alone no result is to be obtained. In other places such as large portions of the Soppeng[174] subdivision, since the Walanaë and the Lemorang rivers supply good irrigation water from a back country of rocks rich in plant nutrients, there is great probability that we may expect much success from good, technical irrigation.

Graadt Van Roggen, the irrigation engineer, has written a paper[175] which is even yet by no means obsolete and very much worth reading, since this author not only shows on a map the projected and possible irrigation works but in his discussion considers the irrigation question from all angles. Yet we are able to find but very little about the soil of the tracts to be irrigated, presumably since what little is known about those soils is so difficult of access that nothing has been published about them through official channels. However, in the already repeatedly referred to Bulletin of the Experiment Station of the Java Sugar Industry[176] by Van Harreveld-Lako and Arrhenius we do find some terrain and soil descriptions relating to irrigated and irrigable plains of Southwestern Celebes. From the data of these workers it appears, among other things, that in the Sawito plain, some soils extraordinarily rich in P occur very close to others very poor in P. Of course this cannot be helped. Still perhaps through long continued regular irrigation of the

173. Report Afd. Landbouw (1928), p. 380.

174. Cf. Memor. v. Overg. Gezagh. H. Cohen voor Soppeng (Sept., 1932), pp. 22-23.

175. J. F. Graadt van Roggen, Bevloeiïngs-en afwat. werken i/d zelfbest, landsch. in ZW-Celebes, De Waterst.-ingen, 16 (Sept., 1928), pp. 279-287, (with 2 maps).

176. C. H. van Harreveld-Lako and O. Arrhenius, Med. P. J. S. I., No. 18 (1927), pp. 759-817.

whole region these differences will be evened up. In the future the use of Sadang water will have a markedly good effect and the "poor soils of Sidenreng"[177] will lose their bad reputation.

Summarizing, we may say that for the many low plains of Southwestern Celebes well regulated irrigation on a large scale is a first requisite for the progress of the agriculture; while for the lowest terrain around the lakes, drainage is at least equally important. But that is not all. Only after adequate water has been made available will it first clearly appear that in many irrigation districts either the soil, or the irrigation water, or both, are far from ideal, and then experiments with fertilizers, green manures, and cultivation of the soil will come into their rightfully important position. It may be expected that then in one locality enormous crops will be obtained, while in other places the deficiencies can hardly, or not at all, be remedied, and the production will remain disappointing.

It seems to me we may expect much from the Goa plain, the plain around Maros, great portions of the Sawito plain and the lands west-southwest of the lakes, but I see much less promise in irrigation from the Bila and the Gilirang rivers in the northeast.

BORNEO

The portion of Borneo belonging to the Netherlands Indies (see the sketch map, Fig. 150, page 384), being approximately 4 times as large as Java and roughly 16 times as large as Holland, has about the same area as France. With a population of approximately 2 millions, something more than a quarter that of the Netherlands, Borneo is indeed thinly populated. And as to the distribution of the population, we find that in the Singkawang, Pontianak, Bandjermasin and Oeloe Soengei subdivisions of Netherlands' Borneo about 2/3rds of the population lives on 1/7th of the area. The rest of Borneo with an area of 14 times that of the Netherlands has a population but little greater than that of Amsterdam alone. Only 1.9 persons per km.^{2} place the region among the thinnest populated parts of the earth and, without doubt, makes one think of conditions in New Guinea.

If, in the first place, we inquire as to what is already known about the geology of this great island, while obviously there remains very much to be investigated, we will be astonished by the large amount of geological information which has already been obtained about Borneo, a land covered by endless tropical high forest. For our purposes, however, it is sufficient to give an adequate survey of the

Soil-Forming Rocks

and this is best done on the basis of a few chapters of the already repeatedly referred-to book by Rutten.[178]

Over great expanses of Borneo Pretertiary formations lie on the surface, although Tertiary formations occupy still greater areas. Much more of both of these formations, however, is covered by Quaternary and Recent alluvia and colluvia, in short by allochthonous soil formations. First something about the rocks themselves.

The Tertiary sedimentary rocks of Borneo differ from those of Java, in so far as those of Java are composed predominantly of marine deposits. Especially in Java, Neogene marls and limestones predominate; while in Borneo the facies is much less purely marine, so that limestones and marls are relatively scarcer than on Java, but shales, loam shales and sandstones occur much more abundantly. By far the greater part of these last-mentioned rocks has been formed from former land or fresh water sediments, having a very much smaller proportion of fossils, but many more coal layers. Therefore in order to determine the age of the different Tertiary formations, one must resort to the kind and the degree of carbonization of the coals.

In general, we may perhaps safely say that the older the deposits are the harder and thicker the clay shales are, and the more solid the sandstones. If we turn from the older to the younger rocks,

177. Versl. Afd. Landb. (1927), p. 446.

178. L. Rutten, Voordr. geol. Ned. O.-Indië (1927), pp. 191-310.

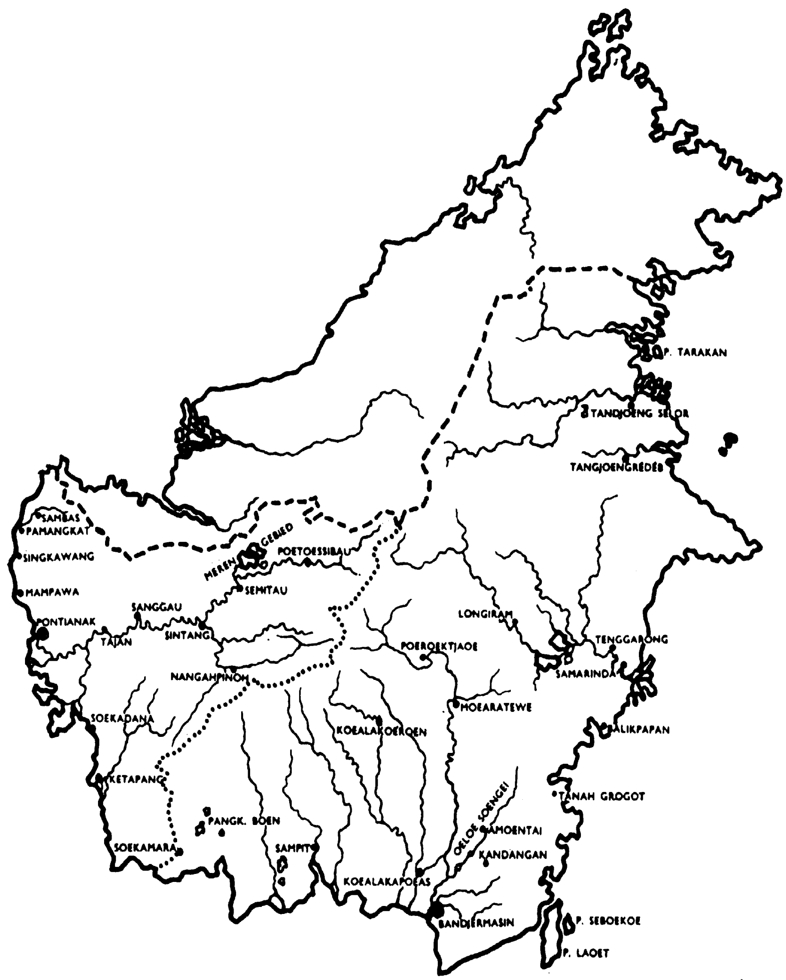

Fig. 150. Sketch Map of Borneo, with place names in the Netherlands' portion.

we find the sandstones looser and finally only loose sand. The clay shales become weaker, and finally consist of soft clay. Regarding the marls, in so far as they occur in the Tertiary, we can say something of the same sort.

The Eogene limestone, found in the hinterland of eastern Borneo, sometimes has splinters of plagioclase as an accessory substance besides the quartz grains which are the main constituent. This would indicate that at that time in the center of Borneo acid eruptives must have come to the surface. For in southwestern Sangkoerilang acid tuffs pointing to dacitic or rhyolitic effusives are also found in the Neogene.

But quantitatively these sandy limestones, or calcareous sandstones, play no role of importance in the mass of sandstones, clay shales, etc. Quartz is far and away the most important constituent of the sandstones. In the loam shales and even in the so-called clay shales the quartz content is without doubt just as high, although analyses of such materials are not available.

The distribution of Tertiary effusive rocks is very limited. In southeastern Borneo there are none at all. In western Borneo this is also apparently the case. Except for a couple of occurrences, as a whole unimportant, these Tertiary effusives are most extensive in the Müller Mts. of

Central Borneo. These effusives are predominantly dacite and rhyolite. Recent volcanoes on Borneo are unknown, but it is possible that at a couple of points in Western Borneo, to the northeast of Pontianak, for example, in Mt. Nioet, volcanoes were active until relatively recently.

Older formations of igneous rocks occur more frequently. There is much granite, for example, in the Schwaner Mts. and very much still farther southwest toward Soekadana and also in the Chinese districts. Also basic rocks such as diabase, gabbro and even peridotite. Besides the granite, in Western Borneo in the Chinese districts diorite, gabbro, norite and diabase as well as quartz porphyry occur. More to the east diabase and diabase tuffs are frequent. In the Meratoes Mts. of southeastern Borneo there is almost no granite, but diabase, gabbro, peridotite and serpentine predominate. The eastern border of South Borneo is an exception to this statement. The last two rocks mentioned above also occur on Poeloe Laoet and P. Seboekoe islands.

There are some other old formations which deserve to be mentioned, such as crystalline schists, which appear at the surface in only a few small tracts, as in the old mountains southeast of Pengaron (Southeastern Borneo); in Central Borneo, along the Upper Barito; and perhaps also in the Chinese districts. Phyllites and glistening slates also occur, especially in Western and Central Borneo. Then there may be mentioned the so-called Danau formation, consisting of quartzite, clay slates, silicious slates, and toward the margins diabase and diabase porphyrite with their tuffs and breccias. These begin to the north of Sintang and extend further eastwards through the whole of Central Borneo and on into northeastern Borneo.

This just about completes the enumeration of the parent rocks of Bornean soils. But a difficulty still remains to be discussed. Everywhere around the edge of this great island the Tertiary rocks lie in groups of strata totalling a thickness of several thousand meters. And upon those deposits are layers of younger alluvium. If one asks himself whence all that sedimentary material has come, and sees on the map the relatively small area of the mountains which are now standing on Borneo, then this question arises: How could central Borneo have supplied all that material?--This led Rutten[179] to suggest the possibility that a part of the material might even have come from farther away, even from the main land of Asia, so that perhaps the "parent rocks" are to be sought also on that continent.

Climate

As to how really equable the climate of Borneo is, appears from the fact that in the large handbook dealing with the climate of the Netherlands Indies by Braak[180] the chapter on Borneo proper comprises but 12 pages of text.

Three important factors work together to cause this uniformity:

1st: the equator crosses the middle of the island, passing through Pontianak, Sintang and Longiram. The climate is thus definitely equatorial.

2nd: even though the area of the island is so large, very little of its surface is high, and what little mountainous land there is rises up steeply out of the plain. It is true that in the northern part of British Borneo the relatively isolated Mt. Kinibaloe with an elevation of around 4,500 m. is present but as to a high mountainous region, there is none to speak of, not even in Brunei. It is true that in Netherlands Borneo, especially on the boundary of the Western and Southeastern subdivisions of Borneo, there are a few mountains, of which a small number of summits rise up higher than 2,000 m. but in most cases even the summits do not reach this elevation. When the contoured topographic map of Netherlands Borneo is issued, it will be interesting to sketch what portions of Borneo would remain above water if the sea rose 500 m., 1,000 m. or 2,000 m. Not even on a map showing a rise of the sea of only 500 m. would we find any great extent of relatively flatland remaining above the sea, although over the entire area of what is now Borneo there would be a number of long

179. L. c., p. 229.
180. C. Braak, Het klimaat van Nederl. Indië, II (1929), p. 401.

and small islands with quite steep mountain ridges, and in addition, a very great number of quite small islands, consisting of isolated peaks sticking up out of the sea, mostly arranged in rows. On the sketch of 1,000 m. submergence there would not be any islands which would be so long, though there would, however still be quite a number of fantastically shaped mountainous islands, without a sign of any flat land. On the sketch of 2,000 m. there would be almost no Borneo; lost in the expanse of the sea there would be only a couple of little islands rising up steeply. Thus Borneo does not have any mountainous land such as, for example, the Preanger of Java, where as a result of elevation there is a different climate, nor does Borneo have any high mountains which markedly influence the climate of the low lands. Thus orographically conditioned climatic differences are only small.

3rd: The final reason is the endless, closed tropical high forest, which covers by far the greatest part of Borneo. This forest has a significant regulating effect on the air temperature, the daily average of which just about everywhere in the low lands, even calculated over the entire year, varies only between 25° and 26.5°C. And the lowlands certainly comprise more than 90% of the whole. If it be possible, the soil temperature under the forest is still more uniform; for example, at a depth of 30 cm. it will be about 25.5 or 26° and at most vary but a few tenths of a degree. Only in Southeastern Borneo have considerable areas been deforested and transformed into cogonals (Imperata spp.). In such grasslands a somewhat higher average temperature must prevail, say about 27 to 28°C. Also a somewhat greater daily oscillation at the surface of the soil occurs. But at 50 to 75 cm. depth in the soil even in cogonals a practically constant temperature will be reached.

It is also notable that the average relative humidity of the air is so uniform. For the different months of the year at Pontianak this varies between 85 to 89%, and at Tarakan between 87 and 90%. Every morning the air is almost completely saturated. This is the cause of the many fogs during the night and the early morning. With saturation, evaporation of moisture from the soil or even from the vegetation cannot occur, so that during only a couple of hours each day can the plants have dry leaves.

And now as to the rainfall. Averaged over a number of years, there is seldom a month with more than 400 mm., and seldom one with less than 100 mm., though of course occasionally rainless months do sometimes occur. The following tables, (Table 85, page 387 and Table 86, page 388), compiled in the usual manner, give a good picture of the distribution of the rainfall throughout the year.

In the Western Subdivision (Table 85, page 387) there is seen to be the greatest uniformity of the rainfall, although close to the mountains of Central Borneo somewhat more rain does fall than around the edge. This is also the case with the Southern and Eastern Subdivisions. During the months from June to September, inclusive, the influence of the east monsoon is universally perceptible but even so there is still not one single monthly average under 100 mm. Calculated over a number of years entire West Borneo is "always wet" and the soil is subjected to only leaching by water.

The Southern and Eastern Subdivision (Table 86, page 388) is for the most part cut from the same piece of cloth but with the following exception. During the east monsoon along the southern coast the climate becomes gradually drier from west toward east. But for all that, the lands which are submerged throughout the entire year get poor satisfaction, for in the back country it continues to rain quite strongly right along. However, if the time ever comes when portions of the low lands behind the coast are diked up and reclaimed, then it is not impossible that in the relatively dry season swamp rice culture could be carried on with success, as is already being done on the west side of Oeloe Soengei and in the so-called "lebaks" of Southern Sumatra.

The Oeloe Soengei exhibits clearly a lower rainfall than almost anywhere else in Borneo. Especially is this the case in the east monsoon in the rain shadow of the mountains in the southeast.--No single station however has less than 2 m. total rainfall for the year.

Samarinda and Tenggarong (Table 86, page 388) have the lowest annual figures,

Table 85

DISTRIBUTION OF RAINFALL DURING THE YEAR IN THE WESTERN SUBDIVISION OF BORNEO[1]

Place		Height above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year	Humid (wet) months	Arid (dry) months
Sambas.........	Along the West Coast	5	41	167	312	202	216	229	206	183	133	180	196	268	320	332	2777	12	0
Singkawang.....	Along the West Coast	3	52	177	363	218	195	207	225	205	171	208	203	351	431	428	3205	12	0
Mampawah.......	Along the West Coast	2	27	137	221	121	145	178	212	215	160	169	217	297	355	323	2613	12	0
Pontianak......	Along the West Coast	3	52	181	285	212	253	284	280	229	164	220	225	376	398	335	3261	12	0
Ketapang.......	Along the West Coast	5	27	160	379	277	237	280	268	178	140	134	183	298	419	480	3273	12	0
Bengkajang.....	North from-- The Kapoeas River	106	26	190	321	230	261	242	252	188	136	183	205	330	325	323	2996	12	0
Balaikarangan..	North from-- The Kapoeas River	about 10	16	172	335	238	276	264	243	179	128	142	288	266	365	302	3026	12	0
Tajan..........	Along The Kapoeas River	7	15	180	296	318	328	293	271	190	173	191	248	342	340	271	3261	12	0
Sintang........	Along The Kapoeas River	27	50	200	340	293	317	318	291	239	198	260	266	341	360	344	3567	12	0
Semitau........	Along The Kapoeas River	30	29	154	362	284	303	327	273	220	196	225	257	314	345	364	3470	12	0
Nangahsoeroeh..	Along The Kapoeas River	about 50	13	181	423	314	388	356	330	210	222	278	318	449	524	434	4246	12	0
Poetoessibau...	Along The Kapoeas River	50	29	119	390	379	380	428	341	269	221	257	284	464	472	423	4308	12	0
Nangahserawai..	South from-- The Kapoeas River	67	11	155	289	242	295	339	269	196	150	171	231	339	308	276	3105	12	0
Nangahpinoh....	South from-- The Kapoeas River	42	22	136	322	270	296	264	255	201	153	161	226	291	322	322	3083	12	0
Kotabaroe......	South from-- The Kapoeas River	103	15	142	277	265	287	296	210	212	151	176	246	259	304	285	2968	12	0
Marau..........	South from-- The Kapoeas River	about 50	11	165	235	228	232	339	245	170	103	110	157	246	359	288	2712	12	0

1. From the figures of Verh. 24 van het Observ. te Batavia, corrected in so far as possible with the data available for 1929 and 1930. Only data from stations having more than 10 years' observations have been used; where the number of stations is large, only a few representative ones have been selected to illustrate the type.

and yet, calculated over many years, neither of them has a single constantly dry month. Tarakan with a minimum of 230 mm. and a maximum of 377 mm. rainfall per month has twice the rainfall but it is just as evenly distributed throughout the year. Here, if anywhere, the lament of Ernst Haeckel is applicable: "This eternal sameness!"

Principal Ways in Which Weathering Occurs and the Resulting Soil Types

Since the climate of Borneo is, indeed, astonishingly uniform, it is obvious that all the differences in the ways in which weathering occurs and in the resulting soil types are to be ascribed either to the differences in the parent rocks, or to the position of the material with respect to the water. Without making any serious mistake we may refer to the soil types lying above the water level as residual or autochthonous because the recent allochthonous material is seldom exposed above water. Conversely, it is only an exception that soil formations occur under water without having a covering of allochthonous material carried on by the water and spread over them, so that pretty nearly everywhere subaqueous or amphibian conditions prevail. Allochthonous material may be accepted as the original material. Taken by and large--and in this book it is, indeed, impossible to consider anything else but generalities--I propose the following simple subdivision of the soils:

a. Soils lying above the ground and river water levels, hill and mountain slopes, and mountain tops with autochthonous kinds of soils, subaerially weathered in a hot to moderately warm, continuously wet climate, subjected to continuous leaching, varying, however, according to the mineral composition of the parent materials.

b. Soils lying under water, (subaqueous terrains), in a hot and also continuously wet climate. Thus with continuously leaching type of weathering in the absence of air. In this case the process differs less because of the mineral composition of the material, but rather according to the grain size (gravel, sand, clay) of divergent deposits of allochthonous soil material.

Beginning with the group referred to above under (a) in the first place the attention should be limited to the Tertiary and older sandstones, which for a great

Table 86

DISTRIBUTION OF RAINFALL DURING THE YEAR IN THE SOUTHERN AND EASTERN SUBDIVISIONS OF BORNEO [1]

Place	Location	Height above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year in mm.	Humid (wet) months	Arid (dry) months
Soekamara........	Southwestern and Southern Coastal Region	3	23	171	268	213	286	276	236	201	125	138	161	213	264	290	2671	12	0
Pangkalan Bon....		9	15	139	224	201	278	293	235	201	132	121	153	209	217	274	2538	12	0
Koealapemboeang..		at sea level	15	119	212	239	245	259	274	183	156	100	92	255	198	225	2458	11	0
Koealakapoeas....		" " "	13	132	323	272	339	266	128	110	54	52	73	130	219	265	2231	9	2
Marabahan........		2	13	125	305	272	294	222	171	106	59	49	83	106	201	280	2148	9	2
Sampit...........	Back country of the Southern Coast	at sea level	29	134	307	267	275	293	244	189	123	104	134	184	227	274	2621	12	0
Kasoengan........		about 80	12	179	285	346	371	323	245	216	110	119	162	233	307	327	3044	12	0
Koealakoeroen....		" 100	30	167	323	349	362	401	333	295	196	214	238	291	375	323	3700	12	0
Poeroektjaoe.....		" 125	28	207	385	314	393	414	322	274	195	203	221	305	371	346	3743	12	0
Moearateweh......		" 30	48	175	307	301	334	317	255	211	137	149	179	232	311	320	3053	12	0
Boentok..........		" 25	48	140	322	279	322	295	213	171	104	101	115	170	308	321	2721	12	0
Tandjoeng........	From the Southeast Coast through the Oeloe Soengei	" 12	21	135	304	291	323	239	195	119	90	89	113	163	231	312	2471	10	0
Amoentai.........		" 20	52	138	299	269	315	230	191	126	91	69	77	121	236	308	2332	9	0
Rantau...........		" 20	30	130	282	236	309	222	173	134	88	77	85	128	218	260	2210	9	0
Pengaron.........		" 30	37	155	320	283	310	219	198	140	97	80	79	132	210	295	2363	9	0
Martapoera.......		" 5	17	121	283	256	260	205	164	93	72	72	61	121	182	283	2052	8	0
Bandjermasin.....		at sea level	52	175	321	304	297	221	160	142	95	83	96	132	216	321	2388	9	0
Pleihari.........		21	14	116	411	308	305	197	145	128	79	67	62	132	208	417	2459	9	0
Asam-Asam........		at sea level	13	175	255	182	257	223	282	259	193	73	89	112	119	253	2297	10	0
Pegatan..........	Southeastern corner	at sea level	19	141	246	242	244	170	207	179	153	109	103	105	141	182	2081	12	0
Stagen...........	Laoet Island	28	25	176	258	254	286	210	239	260	201	159	143	117	180	219	2526	12	0
Kota Baroe.......		at sea level	20	136	272	237	273	197	236	223	220	122	124	114	143	239	2400	12	0
Tanah Grogot.....	East Coast	about 25	13	144	342	231	352	220	184	141	71	83	104	119	173	256	2276	10	0
Balikpapan.......		at sea level	32	141	205	180	239	195	206	195	165	152	132	141	161	207	2178	12	0
Samarinda........	Along the Mahakam and Back country	" " "	25	164	182	160	199	197	183	141	97	95	115	153	196	202	1920	10	0
Tenggarong.......		about 15	17	123	212	129	190	197	183	118	90	86	109	114	186	185	1799	10	0
Moearamoentai....		" 15	21	99	288	185	242	238	196	134	93	92	111	212	243	313	2347	10	0
Longiram.........		30	30	159	340	296	360	411	343	239	178	186	189	266	333	322	3463	12	0
Laham............		50	16	172	318	281	294	419	308	269	218	172	219	269	323	350	3440	12	0
Longbloe'oe......		230	26	173	324	288	315	342	358	261	241	217	257	287	310	363	3563	12	0
Longnawang.......		" 500	13	244	300	261	331	410	367	266	240	261	377	395	423	296	3927	12	0
Tandjongredeb....	Northern Part of the Eastern Coast	" 15	18	170	224	199	212	183	191	158	115	140	155	162	214	217	2170	12	0
Tandjongselor....		at sea level	37	175	266	253	268	222	223	194	190	224	228	249	261	265	2843	12	0
Tarakan..........		" " "	20	208	268	272	360	343	338	332	230	308	291	352	377	350	3821	12	0

From the figure of Verh. 24 of the Observ. te Batavia, corrected in so far as possible with the data available for 1929 and 1930. Only data from stations having more than 10 years' observations have been used; where the number of stations is large, only a few representative ones have been selected to illustrate the type.

part consist of quartz. What sort of soils can these rocks give rise to?--Little else than quartz sand and quartz flour; the latter being the result of further mechanical grinding. But more about that under (b). Since the cement which binds the quartz grains of the sandstones is also silicious, about the only way these rocks can weather is physically; for example, through temperature differences, bursting or cracking repeatedly, and becoming broken up. Vegetation is only possible on such material after wind or flowing water has carried onto it something or other which can be used as food by the plants. In Borneo sandstones with calcium carbonate cement weather through leaching out of the lime, leaving behind a mass of loose quartz grains. Whether on such a residue vegetation can develop and exist, be it ever so poorly, will also have to depend upon the amount and value of the impurities. Sandstones with a clayey cement, or where mineral grains, such as feldspar or hornblende are mixed with the quartz grains, can, of course, weather chemically, because when these minerals weather clay is one of the products. That is to say, the minerals other than quartz weather, so that considerably better vegetation is possible on the sand or sandy soil so formed. The growth may hardly be excellent, but it will still be good for quite a time. In the course of a long time, especially where the surface of the soil is about level and there is no appreciable erosion from the surface, the clay washes down into and through the upper horizons of the soil, and on the surface a bare, white sandy layer remains. In short--the many kinds of quartz sandstones on Borneo, to whatever geological formation they may belong, all give rise to silicious sandy soils which, from the standpoint of the vegetation, must be considered among the poorest of all soil types.

As has been said, the clay shales for the most part must also be considered as land or fresh water sediments. When these weather under the given weathering conditions they take up water, and in doing this they swell and disintegrate, but much more slowly than if they were marine sediments, in which case they would be more or less marly. These clay shales gradually change into a heavy, "sticky" kind of clay. When wet this clay is impervious, tough, and solid and so long as it remains continuously wet it is satisfactorily resistant against erosion. If however this material is exposed and dries out, for example as a result of deforestation and kaiñgining, then the clay becomes granulated and broken up and is easily eroded by the wind or water as, for example, is the case on Timor. Fortunately on Borneo, for the time being, this kind of erosion is an exception, rather than a general condition.

Obviously also on Borneo there are found members of a group of rocks which lie between the sandstones and the clay shales. Sometimes these are about the same as the sandstones, at other times, more like the clay shales. Loam shale seems to me the best name for this group of rocks. The grain size of the particles lies between 50 mu and 5 mu. Since the individual grains cannot be seen with the naked eye, these rocks ought not to be called sandstones. Yet the clay content is much lower than that of the true clay shales or claystones, so that upon weathering these rocks do not swell so much. It is of course obvious that quartz grains measuring between 50 and 2 mu. cannot swell from the taking up of water. Therefore the loam, which exists as a residual soil originating from such shales is physically different. (This was discussed more fully but in more general terms on pages 186 ff.) Especially when this loam is somewhat more sandy, that is, a light sandy loam, it is a substratum on which many more crops, as well as more bushes and trees can grow, than if it contains more clay and is a heavy loam. Yet these soils from loam shales are no more able to meet high crop requirements of fertility, i.e. adequate water and food supply, than the soils on the sandstones and clay shales. Meanwhile, each soil type carries its own flora. Trees are on the soil on the sandstones, since if they have enough water around the roots they can get along in spite of an inadequate food supply. On the clay shales are trees which can form an adequate root-system even in the tough clay and can obtain the small amount of water which they must have, providing only that this smaller amount of soil moisture has a somewhat higher concentration of plant

food.

No matter whether the weathering produces coarse blocks, small silicious rock fragments, quartz sand, or loam or clay rich in quartz flour, the quartzites, silicious slates and clay slates of the Danau formation cannot give rise to any other kind of soils than very poor quartzitic or silicious ones. Molengraaff[181] has already stated this to be the case.

Better soils develop from marls, as long as there is still some lime left. The soil is more flocculent and pervious; and since the clay, which had settled down with calcareous organisms through the salt water to the bottom of the sea was able to absorb more bases, the weathering soil developing on rocks with such an origin is at first richer chemically. On the other hand such soils have disadvantages, such as the bulging out, the "creep," and the more rapid disappearance of the surface soil through erosion. Of course as the process continually exposes new marl particles at the surface and facilitates weathering the rejuvenation of the soil occurs. Soils derived from marls are troublesome to cultivate.

We now come to a discussion of better soil types, namely, those on the igneous rocks. On the granites and quartz porphyries, which occur especially in and around the Western Subdivision of Borneo, the soils have formed under continuously wet climatic conditions. There the feldspars, the micas, and eventually the amphiboles have weathered into a lixivium which contains quartz sand and is colored yellow, brown, or red with iron oxide. The granite along the Kapoeas is "deeply weathered and altered into yellowish brown laterite"[182]; Molengraaff also remarked[183] that "richer weathering soils are developed from granitic massives; around Mt. Menjoekoeng are found the most fertile spots in the lake region." The expression "most fertile" is of course to be taken in a relative sense, since from the description of the Celebes the reader already knows that andesites, basalts and leucite rocks, for example, give rise to significantly more fertile soil types than does granite, especially the forms which are the richest in silicic acid.

Besides the already mentioned silicious slate, etc., there also occur in the Danau formation diabase and diabse porphyrite with accessory breccias and tuffs; rocks, which in general, weather to a lixivium, and which also give rise to quite decently fertile brown and brownish yellow soil types. But before now, during millions of years which have passed, these rocks "through decomposition and silicification, connected with dynamometamorphosis," have already been weathered many times and they have been altered and permeated by numerous quartz veins and fully serpentinized on the clay faces."[184] By these processes they have not been enriched, and "in a thin layer on the rock" there now lies a "tough, yellowish brown infertile clay," while normal diabase "weathers deeply to brown clay."

However, what washes off from such diabase rocks through erosion and mixes with the products of erosion from the previously mentioned quartz-rich and silica-rich rocks, because of higher concentrations of iron hydroxide, of bases carrying plant nutrients, and of phosphorus, cannot help but improve the soil.

As the rock is more acid, i.e. contains more SiO_2, less iron, less P, etc. all of the soil on the dacites and rhyolites of the Müller Mts. and elsewhere where such rocks also sporadically occur, is again less fertile than that on the diabase and diabase tuffs.[185] It is a pale yellow clay, with quartz crystals in it. Such a soil cannot be rated very high either as a fertile, residual one or as a source of good allochthonous deposits. In the course of both subaerial as well as amphibian weathering of the difficultly pervious soils and rocks of Borneo, under the continuously

181. G. A. F. Molengraaff, Geol. Verk. tochten Centr. Borneo (Leiden 1900), p. 131: "Soil, which does not ordinarily stand under water, is infertile. Fertility is not to be expected from silicious slates, quartzite . . . and sandstone."
182. Molengraaff, l. c., p. 7.
183. Molengraaff, l. c., p. 131.
184. Molengraaff, l. c., p. 91.
185. See for analyses: Tables 3, 4, 7.

Photo by C. W. A. P. 't Hoen

Fig. 151. Solid laterite exposed on the Koekoesan Mts. (Soengei Doewa) Southeastern Borneo. On these hard, stone-like masses of brown iron ore nothing can grow. (See pages 347-349, 391-394.) (Photo from the Jb. Mijnw. (1921), Verh. I, p. 288.)

wet climate which prevails there, the weathering of iron-containing material and the translocation of iron-oxides and their precipitation in all sorts of places and in all sorts of forms must be expected to occur. Molengraaff described[186] how limonite had been deposited between the layers and in the cracks of the silicious slates, the angular pieces of which remained clear white. It is notable however that the formation in the soil of, or of the transformation of, iron concretions such as hail iron ore, bean ore, or larger, kidney shaped concretions (krikil), is seldom mentioned elsewhere. Yet such concretions must occur on Borneo, just as frequently as on Celebes, Sumatra, and Java. In road cuts behind Balikpapan I have identified various sorts of iron concretions.

However, whenever iron concretions have been found in such quantity and concentration that they have been considered a possible source of iron, then they have attracted the serious attention of the geologists of the Bureau of Mines.[187] As would be expected to be the case, massive occurrences of concretionary iron ore are found on such ultrabasic rocks as peridotite and serpentine, on the islands Seboekoe(t), P. Danawan, P. Soewangi and on the Koekoesan Mts. (Soengei Doewa) of Bornoe itself, as well as in the Pleihari Subdivision (see Fig. 151). These deposits are entirely analagous to those in the

186. Molengraaff, l. c., p. 90.

187. In No. 7 of the Versl. en Meded. betr. Ind. Delfst. enz. (Batavia, 1919) we find on pp. 48-60 a summary of obviously all Netherlands Indian data relating to such ores, up to that time known to the Bureau of Mines.--No. 9 of this same publication (1921), deals with the more important iron ore deposits in Borneo; it is based upon a report by Ch. A. F. Macke. The following may also be referred to: W. Dieckmann, Ijzerertsafz. Koekoesangeb. ZO-Borneo, Jb. Mijnw. (1920), Verh. I, p. 70-86; W. F. Gisolf, Bijdr. Kenn. waarsch. genese ijzerertsen Koekoesangeb, Jb. Mijnw. (1921), Verh. I, p. 296-303; C. W. A. P. 't Hoen, Div. meen. over ontstaanswijze ijzerertsen ZO-Borneo, Jb. Mijnw. (1921), Verh. I, p. 288-295.

Verbeek Mts. and elsewhere in Southeastern Celebes, although there are also complications which occur, for example, (1) it is more likely that here and there in these parent rocks in southeastern Borneo there were already originally present accumulations of magnetic iron ore; and (2) that, as it began to weather, the peridotite or the serpentine apparently was not exposed directly to the atmosphere, but rather it first lay submerged under an Eogene deposit, which afterwards completely disappeared. Meanwhile leaching-out weathering progressed. The consequence was that first there developed an intermediate stage caused by the Eogene material from which through weathering (the ceaseless leaching), caused the development of the peculiar "greenish ore" as well as its being carried away.[188]

The requirements of the mining engineer demand that a large number of borings be made, and that large numbers of samples of ore obtained in this way be assayed. Yet the large number of analyses which have been so obtained cannot serve for our purposes in the study of soils. This is because at critical places in the profiles some gaps prevent our obtaining an accurate conception of the course of the weathering and soil formation. We find that all borings were discontinued when there was no more ore. The underlying rock, however, whether it be serpentine, or the original peridotite is indicated in the profiles,[189] sometimes with a sharp boundary, at other times with a vague one, with weathered soil material lying on it. But none of the accompanying analyses are of material farther downward than the "ore." Not even as an exception was a single bore hole completely analyzed to the bottom. The analysis of "average samples obtained by mixing proportionally all samples from each hole" was apparently entirely justified for the purposes of the mining engineer but for obtaining an insight into the course of the weathering, the analysis of such samples is entirely useless. While layer samples made up from a number of handfuls out of very divergent sample bores were also analyzed, yet such analyses are more confusing than illuminating. Finally it must also be mentioned that only in a few cases in the analyses was Ti determined, while in many the Ca was not determined, in all of them figures for the alkalies are lacking, even in those where Al_2O_3 sometimes occurs to 12% and more, even though such amounts could not have existed exclusively in the picotite form in the rock and thus must be thought of as having existed in part as a constituent of the pyroxene. Hence very likely there must have been a considerable Na or K content.

As to the research of the pre-eminently expert mineralogist-petrographer, Gisolf, it can here only be deplored that of the series of samples investigated from rintis II well 7, the figures for the head and the tail samples are lacking. Regarding the above profile this question remains unanswered, namely as to how the Al_2O_3 occurs in the extremely solid layer of iron oxides. Is it hydrargillite and in that case is the ore an iron-rich bauxite? And likewise, referring to the lower part of the profile, what is the mineralogical composition of the parent rock, the peridotite, under the serpentine? How thick is the serpentine layer? What is the nature of the transition from peridotite upwards to the lowest "ore layer" which has been analyzed?

It is, of course, to be understood that the above digression is in no sense a criticism of the investigation in the interests of mining. Because for me to make any such criticism would be most unbecoming. My only intention is to point out that if all the bore hole samples had been preserved separately, by using them it might have been possible to clear up very many, though perhaps not all, of the indicated deficiencies and could perhaps have brought about a clarifying reconciliation of the different conceptions[190] regarding the process of formation of the ore.

Although various questions still

188. Cf. the publications referred to by Dieckmann, Macke, and Gisolf.

189. See in Macke, l. c., plate Ia.

190. 't Hoen, l. c. placed the three conceptions of Dieckmann, Macke, and Gisolf side by side and pointed out the conclusions which result from such a comparison. However, only new borings will make possible a complete clarification of the situation.

remain unsolved it seems to me that the conception of Macke deserves to have the greatest value ascribed to it.

The most important of those unsolved questions is certainly this: through what means does the earthy iron ore (on Celebes it is called "loam ore") come to be "baked" together into the solid mass of ore or laterite?--The profiles of Dieckmann and of Macke strongly suggest that the "baking" (cementing) occurs on or near the surface, though ascending soil moisture cannot be the cause of that, for it is difficult to accept any other water movement but a continuous or intermittent one from above. The end result of this final leaching is that no water-soluble constituents are left and the vegetation succumbs (see Fig. 151). If one takes into consideration that many substances in the impure state crystallize with difficulty, if at all, though they will readily crystallize if they previously have been purified (in the discussion about Bangka this point will be mentioned in connection with kaolin), then to a certain degree it appears possible to believe that the purest iron oxide is the first to crystallize and, indeed, in this way a few submicroscopic crystals grow at the cost of their neighbors, which they are inside of or next to. Then this crystallization (the formation of the solid iron ore layer which in that case corresponds the best of all to the conception "laterite") takes place from above downwards, the mass becoming gradually and continually more difficultly pervious. Perhaps the gradual disappearance of the vegetation, which cannot live on water alone, contributes to the formation of the solid iron ore layer, in that by leaving the surface exposed to the sunshine the surface temperature can rise very materially. But much importance can never be ascribed to this, since the solid iron ore layer or fragmental ore extends to depths of from 1 to 3 m. and more and the heat of the sun certainly does not penetrate to any such depth. So for the time being the only explanation(?) which remains is not much else than that in the course of a long time it is the tendency of the iron oxyhydrates to lose or to push off their combined water (hydrophobia); and in addition we may ascribe some of the effects to time, "the general utility man" in geological processes, who is called in to help explain processes which are not understood.

On Poeloe Soewangi there is a fragmental iron ore which "apparently originated directly from the weathering of the serpentine, thus without the intermediate stage of clay formation having taken place."[191] How can this be made to agree with the statement just a few lines above? "over almost its entire extent the serpentine weathered to reddish brown clay"; only locally on the north slope does "solid serpentine appear"....."Also in connection with the lower value (less than 40% Fe) of the weathering clay (from the mining standpoint--E. C. J. M.) fragmental ore formation on a large scale has not taken place." .....What Macke has in mind is again the true conception of "laterite," in contrast with the first mentioned, wherein he considers that the serpentine has changed directly into fragmental ore.

Here we may merely recapitulate that it is by no means proved that the fragmental ore or a solid ore (laterite) layer must necessarily have originated as a hard surface crust. Where such ore is found, layers of Eogene material overlay the serpentine which was on the peridotite, and it is in no sense impossible or improbable that the water percolating through these Eogene materials had had an influence on the formation of concretions in the boundary layer of that Eogene with the perhaps more or less broken up uppermost portion of the serpentine layer, wherein perhaps movement and sorting had already taken place before the Eogene layers had come to lie on them so that the magnetic iron ore might have accumulated here and there. (This should also be able to explain the high lime content in a couple of the analyses given by Dieckmann.[192]) These "fragments of serpentine, directly altered into fragmental ore" could then have originated in the zone of fragmentation and could have come under the influence of iron-containing liquids coming from the Eogene rocks above, before the latter had all been eroded away.

191. Macke, Versl. en Meded. enz., No. 9, p. 21.
192. Dieckmann, l. c., p. 75, analyses Nos. 2 and 5.

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If we now turn from a consideration of the autochthonous, residual soil formations to the group of allochthonous soils mentioned above, we should first of all refer to a paper by Feuilletau de Bruyn[193] about the Oeloe Soengei, in which he deals with the rivers and the soils which are found there. It is true that this region is only one particular part of Borneo, but the differences between it and the rest of the low lands of Borneo are relatively small, so that if one knows this region well and understands its characteristics, the rest of the low regions along the rivers can give but few additional surprises. Feuilletau de Bruyn clearly describes the Negara river, how the principal rivers build up their banks with the somewhat coarser silt carried along by them, while the swamps lying back of them are isolated during low water. But during high water the swamps are flooded and finer sediment is deposited in them, while the "pematangs," the river banks of the countless former beds of the rivers run through the entire land in various directions and divide up the marsh plain into smaller portions.

Of course these river banks consist of somewhat coarser material. Many times they are lighter, sandier loams. Back of them, thus farther from the river, are the heavier loams and finally, in the lowest portions heavy clay is deposited. So it depends upon where the river comes from, as to what the soil types are. If the upper portion of the river valley possesses much (mostly Tertiary) limestone and marly chalks, then the water is rich in lime, the pH is thus high. The silt is also calcareous and may be rich in $CaCO_3$, and as a consequence the deposits also are still calcareous. The result is that there is no peat formation, barely a little humous deposit (see Fig. 155, page 401). On the other hand if the upper portion of the river valley consists of rock poor in lime, but rich in silica such as schists, sandstones, etc., then the water and silt are poor in lime. While the pH in the river may originally be still above 6, down lower in the swamp the value may fall to below 5, to 4, or to even less than 3. This extremely low figure, for example, is the case in West Borneo, in the lake region, and also in the coastal region behind Soekadana and Ketapang. And in the Oeloe Soengei one need but to cross the Negara east to west to come into the region of the Barito to observe extensive and deep peat formations. Van der Laan[194] notes the following about these peats: "Also on Borneo these low peats occupy great areas and occur in meter-thick layers. It is especially the herbaceous swamp plants,....water ferns, rushes, etc., which contribute the most to this peat formation. Sometimes in dry years, as in 1914, the peat soil burns up over great areas."

As all these formations have already been discussed above in a general way on pages 183-186, it will suffice to refer to that treatment and to here note certain local peculiarities.

In the successive forms of gravel, sand, and silt the colluvia and alluvia of the large Borneo rivers have a long journey to make from far back in the hills where they originally enter the stream to the places where these materials are finally deposited. This journey has not left them unaltered. The gravel is broken up into smaller and smaller pieces, the sand is ground up finer and finer by the gravel or rather the grains are crushed more and more, while the suspended silt undergoes the least mechanical alteration. But in so far as they are still in a state to be weathered, these finest particles are the very first to be altered chemically. Lime, for example, for the most part can exist only in short rivers coming from river basins in which there are marls breaking down relatively easily. But when these rivers empty into larger ones coming from drainage basins, portions of which are poor in lime, with most likely also somewhat acid water, then it is clear that on Borneo alluvium containing calcium carbonate must indeed be scarce. Even feldspars, pyroxenes, and amphiboles cannot last through

193. W. K. H. Feuilletau de Bruyn, Bijdr. kennis Afd. Hoeloe Soengei (Z. en O-afd. v. Borneo), Kolon. Stud. 17 (1933), p. 53-93.
194. E. Van der Laan, Bosschen v. d. Z. en O. Afd. v. Borneo, Tectona XVIII (1925), p. 936.

Photo by F. H. Endert

Fig. 152. Central Eastern Borneo, near Mt. Antjaloeng. The fantastic root formations above the surface of the ground show that very close under the surface the soil is without air and is as good as impenetrable.

all that long journey. Only quartz powder remains unaltered and is deposited with the minerals which have resulted from weathering and which are included in the "clay."

In the lake district, in the back part of the Western Subdivision of Borneo, Molengraaff found brown water[195] in the lakes, whose banks exhibited an alternation of sand and loam layers with thin layers of peat. From descriptions of different portions of New Guinea, especially the extensive swamp tract in East Netherlands New Guinea, to the south of the high mountains, the reader is already familiar with these hopeless landscapes. The enormous region of Borneo included within the lines connecting Sampit--Moeara Tewe--Bandjermasin and the south coast, is exactly like it,[196] as is also a great deal of Koetei with the lakes in the south of that region. The coastal plain of western Borneo, in which lies Pontianak, while very similar is not exactly the same, in so far as this region has some marine clay, the physical and chemical conditions of which are better. The marine clay has been enriched by absorption and so is more fertile and has been planted to countless cocos. The pure river alluvia however are poor, for they are undeniably leached. Reserve capital in the form of still weatherable minerals is lacking, and the floating soil capital, the absorbed nutrient plant materials have to a great extent been washed away. The clay is genuine "hydrogen-clay" with a strongly acid reaction (see Figs. 152 above and Figs. 153-154 on page 396).

Now why is the Oeloe Soengei a relatively favorable exception for Borneo? --(1) because the climate is more favorable there than anywhere else. Lying in the southeastern part of Borneo, in the

195. L. c., p. 43.
196. Cf.: H. Frijling, Bijdr. geol. Kotawaringin en Ketapang, Jb. Mijnw. (1918), Verh. I, p. 211.

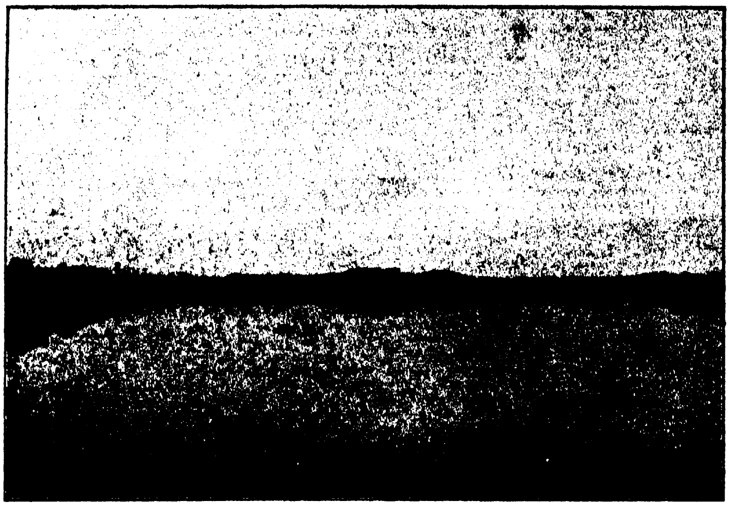

Photo by E. C. J. Mohr

Fig. 153. Koetei River, down stream from Samarinda, Eastern Borneo. Low and weakly rounded hilly land; where the soil is 1 m. and more above high water level it is red and yellow, when lower it has spotted and variegated colors, and close to the ground water level it is gray. Infertile fine sand is everywhere along the river; vegetation gets its food from the water, since there is none to be had from the soil.

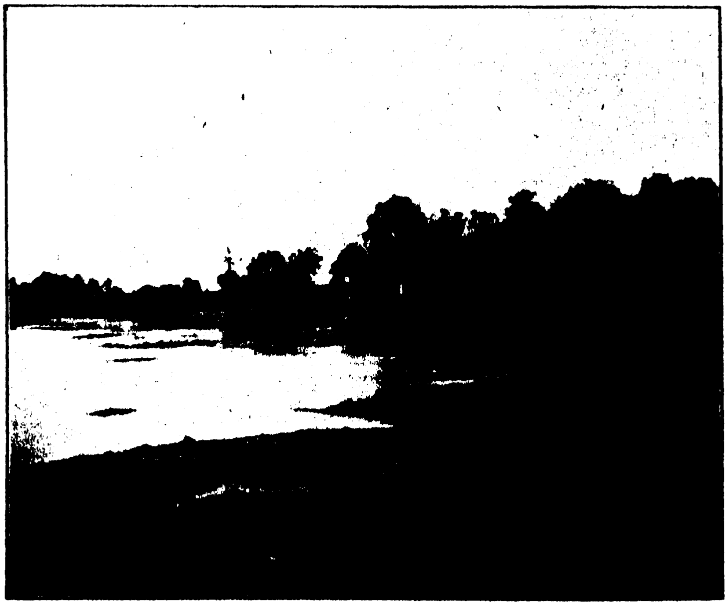

Photo by F. H. Endert

Fig. 154. Central Eastern Borneo. Koempai grass (Panicum stagninum) a type of Bornean marsh vegetation, coming down the Moentai river in floating islands. River bank with better forest on lighter ground.

Table 87

ANALYSES OF RIVER WATERS

	Batang Ali	Awang Amoentai	Soengei Empesoek	Soengei Kedang-(an)	Soengei Mahakam	Moesi 1	Moesi 2	Soengei Kwaloe	S.Beengoe Bone	'S. Bantimoeroeng
	Oeloe Soengei Southeastern Borneo		Western Borneo	Eastern Borneo		Palembabang		Sumatra's East Coast	Southwestern Celebes	
	milligrams per liter									
SiO_2	1.4	1.8	2.6	8.0	8.8	11.6	7.0	35.1	15.4	12.0
Fe_2O_3 Al_2O_3	0.9	0.8	1.2	2.4	3.2	1.6	0.8	3.2	0.8	0.8
MgO	2.8	2.9	1.6	5.9	3.2	1.2	1.9	0.5	19.1	2.3
CaO	19.5	17.2	3.4	6.0	6.0	4.6	4.8	3.4	54.2	75.0
Na_2O	10.7	10.0	5.7	6.7	3.7	5.8	4.7	9.9	18.6	9.8
K_2O	2.1	1.2	2.6	2.8	1.4	1.9	1.6	4.5	1.5	3.6
Cl	0.9	2.0	5.5	1.2	1.6	2.1	4.9	0.9	11.4	4.2
SO_3	4.2	3.6	3.5	9.4	4.4	6.9	4.0	1.2	13.5	8.0
P_2O_5	sp.	sp.	0.1	0.1	0.2	0.1	0.1	0.5	0.2	0.1
(CO_2)	(24.1)	(21.2)	(4.3)	(11.3)	(8.1)	(4.8)	(4.7)	(11.1)	(63.1)	(63.1)
(Total of the constituents)	(66.4)	(60.3)	(29.2)	(53.4)	(40.0)	(40.0)	(33.3)	(69.6)	(195.0)	(177.8)
Dry matter	70.8	65.4	39.2	54.6	44.2	44.6	38.6	71.9	196.2	179.8
Loss on ignition (Organic matter + H_2O)	8.4	8.0	13.0	6.2	4.0	8.6	10.4	11.1	22.6	5.2
Residue after ignition	62.4	57.4	26.2	48.4	40.2	36.0	28.2	60.8	173.6	174.6

Note: All values are given in milligrams per liter. The values within ( ) are only calculated; those for CO_2 have been deduced from the difference between the basic and acidic equivalents. The reason why various small rivers have been studied and big rivers, such as the Barito and Kapoeas have been omitted, is because these analyses have been made as a part of the study of irrigation possibilities.

rift in the mountain, between Mt. Satoewi in the south over Mt. Hantang to Mt. Loewang, in the east monsoon Oeloe Soengei receives significantly less rain (see Table 86), yet there is no definite dry season such as, for example, Makassar has. (2) Since the region lies quite close to the mountains only short rivers are needed to carry the water from them into this region during the west monsoon. (3) Because the mountainous land is composed of a wealth of all sorts of rocks, which are the source of relatively rich silt and river water (at least certainly rich for Borneo). Because of these reasons the Oeloe Soengei is also the least thinly inhabited region of Borneo.

That the rivers of the Oeloe Soengei are indeed richer in lime than various other rivers of Borneo, is evident from the analyses[197] in Table 87 above, wherein for comparison are included a couple of Sumatran rivers of comparable nature, besides a couple of Celebes' rivers from genuine limestone regions.

Thus it is evident that the lime content of these Oeloe Soengei rivers is higher than that of the other rivers of Borneo, though in comparison with those of Celebes the amount is but moderate. While on Java there are rivers with a lime content of even more than 100 mg/l.--Also the phosphorus content is low. Rivers in whose drainage basins occur young volcanic products usually have higher values (Sei Kwaloe). In comparing these figures with

197. The Institute for Soil Research at Buitenzorg, Java, in 1931 kindly supplied for my use a transcription of a considerable number of analyses of river waters, carried out by W. Weber, but up to the present time (1934) these have not yet been published.

those of spring water from young volcanic regions (cf. Table 40) it appears that the latter have much more silicic acid in solution, while the Borneo rivers have more iron. This is exactly as would be expected.

In the course of a long time portions of the river banks may come to lie high enough above the water level so that there, at least in the surface soil, subaerial conditions are able to prevail. The rest of alluvial Borneo certainly lies under amphibian conditions. This means continuous leaching under water, of all bases, as well as of iron, the clay in the soil becoming more and more heavy and impervious. Thus gray to bluish gray colored soils develop with more or less acid humus in or on them. If these soils are sandy, then they are of such a nature that if a sample is dried out and ignited, snow white quartz sand is all that remains behind. If they are rich in clay, then they may vary between light or heavy loams on the one hand to stiff hard pale clay, from which one can no longer make the ordinary bricks, but rather, more or less true fire brick, since even the last traces of alkalies, lime and magnesia, as well as iron, have been carried away. Upon quartz fragments and kaolin alone no plant can exist. Hence what vegetation there is lives most extremely frugally upon what new water flowing to the place may bring with it. It is evident that the vegetation can consist of only slowly growing shrubs and trees. But if from such a senile terrain the vegetation has once been thoroughly grubbed out, it does not easily return again. Only after excessive floods coming from the high back country, which bring along with them and deposit relatively much silt which is not too much leached out, is it possible for plants to again develop. Only in that thin uppermost layer of the surface soil will the vegetation develop and with a horizontally widely spread out root system in a literal sense will remain "standing" on the soil (see Fig. 152, page 395).

Evaluation and Utilization of the Soils

At the beginning of this chapter dealing with Borneo the reader has been prepared for a comparison of this island with New Guinea. Why this is the case in many respects will presently be explained.

If at times here and there in our travels about Borneo it has seemed that in comparison with the natives of Java or of Bali for example, the native inhabitants are too indifferent, too slothful and too backward, we should stop to consider that the differences are based upon completely different causes. Where but little is to be obtained from the soil of an agricultural region, the natives have gotten that, as the Oeloe Soengei and the northwestern coastal strip of the Western Subdivision of Borneo adequately show. And it is very much a question whether in those regions where there is now nothing, where not even once in a long period of years is rice planted, whether even with so-called modern western methods of assistance, such as plows and other agricultural implements and machinery as well as with fertilization, can a really satisfactory result be obtained. The soil must be suited to the crop, and land and water must work together, otherwise the case is hopeless.

Suppose one has a heavy, subaqueous clay soil, composed largely of the so-called hydrogen clay. Superficially one might most probably simply say: draining and generous fertilization will produce a harvest from this land. But if we stop to figure out how much calcium, potassium, magnesium, and phosphorus we would have to add in order to convert this clay into a useful soil with a moderate base saturation, then we arrive at such enormous amounts that it is clear that it would be quite impossible to develop an agriculture which would pay. In order to make this clearer, let us make the matter more concrete with a few figures: the hydrogen clay is perhaps less than 5% saturated with bases, as contrasted with being more than 95% saturated with hydrogen. To make this soil productive the base saturation should be raised to around 70%. Thus Feuilletau De Bruyn[198] says quite truly, and this applies especially to the pick of all the districts of Borneo, the Oeloe Soengei: "The way in which the natives of Hoeloe Soengei work their paddies makes a poor impression upon the superficial

198. L. c., p. 70.

observer. But no matter how primitive this rice culture may appear to the eye, yet under the circumstances it is in reality the most rational way of doing it."

Rice is planted both (a) on upland soils, which are not flooded, and (b) on soils which, while for most of the year are submerged swamp lands, yet are periodically exposed.

a. On the upland soils (not flooded) the Dajaks really plant only rice and they continue to plant it just as many years in succession as that is possible. On the "richest lands," this may sometimes be as much as 2 to 5 years in succession, however, in by far the largest number of cases but one crop can be raised,[199] after which the land is allowed to lie fallow for perhaps 10 years, and sometimes even as long as 15 years. As to yield, Uljee mentions that "for the kaiñgins of the Dajaks this is ordinarily taken to be 20 piculs paddy." That may be correct for the better lands, but for a general average this figure is apparently much too high, since it is but seldom attained even on upland rice fields on Sumatra and Java.

Meanwhile exact figures are still lacking. It is surprising that in the Reports of the Agricultural Extension Service,[200] during the first years after this had been established on Borneo, there was not a word mentioned about cultivation of rice. In the beginning the reports dealt entirely with the production of rubber, later they have also included the cultivation of coconuts and pepper. Apparently as long as there are profitable commercial crops to be dealt with, the food crops remain entirely in the background. Borneo thus offers an entirely different picture from that of Celebes and of Java, where the food crops are the most important, and plantation crops occupy a secondary place. If, however, simple kaiñgins really did yield an average of 17.4 quintals per ha. paddy, we may rest assured that there would have been a much more extensive and intensive cultivation of rice and other food crops, and as a consequence a notably greater density of population than is actually the case.

It is worthy of note that following Uljee's estimate of yields of 17.4 qu. ha. (20 piculs) of paddy for the Dajak kaiñgins, he considers that "the Pontianaks on the coast average 21 to 28 quintals per ha. (24 to 32 piculs) paddy. "In the Chinese districts frequently two crops a year are raised so that the (annual) yield is doubled." How is that to be explained?--In this connection it might merely be mentioned that while Moojen[201] did everything possible to establish a regular lowland rice culture in Pontianak he frankly admitted his failure. Also Later[202] mentioned the only mediocre success of lowland rice culture in Landak. In consequence exact figures relating to lowland rice culture are very much to be desired since, speaking generally, it is difficult to believe that if an industrious native people such as the Dajaks are able to produce 17 quintals paddy per ha. and the Malays 21 to 28 quintals per ha. why it should not be cultivated more extensively and why the density of the population should not be greater than it is.

On the other hand Moojen mentions the "outstanding coco soils," the low sandy banks along the coast, which certainly contain some clay, that is, they are really a sandy clay; here also should be included "the high lands (pematangs) on Padang Tikar, consisting of sand and clay." Spaan[203] speaks of "relatively small strips of clay along the coast (of Sambas), where the Chinese farmers really harvest from their cocos 30 to 60 and more nuts per tree per year, while annual crops are not worth mentioning. Since the "peat marsh soils" lying behind the low sandy ridges "are less suitable for cultivation" they are allowed to remain under heavy forest. Uljee writes:[204] "The Coastal tract is almost one continuous coco palm plantation. By comparison, the areas of paddies, sago palm gardens, and nipa pale into

199. Cf.: G. L. Uljee, Handb. Westerafd. Borneo (Batavia, 1925), p. 64; J. F. Later, Mem. Overg. Gezagh. Landak (1919), p. 17.

200. Afd. Landbouw, Verslag, 1927, 1928 and 1929; later reports have not appeared.

201. J. G. Moojen, Aanvull. memorie Pontianak (1922), p. 2.

202. J. F. Later, Memorie landschap Landak (1919), p. 33.

203. Spaan, Nota Sambas (1933), pp. 9 and 22.

204. L. c., p. 68.

insignificance. It is thus desirable not to give an exaggerated impression, since "the strip of land, which is planted with cocos, varies in width from 2 to 8 km." It is indeed a very narrow border along the coast. Behind this fringe, where the marine clay has been leached out with fresh water and gradually changes to poor, acid, peat marsh soils, cultivation is no longer possible. We should also keep in mind what Moojen states, "in some places in 400 years the shore has extended seaward 8 hours walk (40 km.)." This amounts to an annual increase in the land of about 100 m. width. The various stages in the advancing of the shore line are apparently about as follows: Along the sea there is a narrow strip of land suitable for cocos, this continually grows out to the west and will be planted. In the east, however, as the acid peat water leaches the soil colloids and transforms them into "hydrogen clay" which to a great degree had been rapidly saturated in the sea, the resulting soil is exhausted, infertile, and is abandoned.

This phenomenon is of course not limited to western Borneo, but is also taking place along both the southern and eastern coasts of this gigantic island.

b. Where paddies have been mentioned above, these must not be confused with the kind of paddies which are found on Java, Celebes, etc. These paddies on Borneo really ought to be called marsh paddies or still better marsh kaiñgins, for such rice fields are not regularly irrigated. We are here dealing with low lying lands, which in the rainy season are submerged. In the "dry season" (better called the season of less rainfall) the lands are gradually exposed and then as rapidly as possible the paddies are planted. This season of less rainfall continues for a few months and during this time the rice can develop and ripen. If because of abnormal drought the drying out of the land occurs too rapidly, then the crop fails because of lack of water. If the rainfall is excessive, the crop is drowned and in this case, too, there is no harvest. The modicum of plant nutrients which the annual flooding brings with it, as a rule makes it possible for these marsh kaiñgins to be planted for a somewhat greater number of years than kaiñgins which are always above flood level. Still, in most cases, after 2 or 3 years even these paddies must also have a couple of years rest. Only here and there in Oeloe Soengei do they continue to plant the same fields longer. It can be done there because the nature of the irrigation water and of the climate help to make it possible.

As a crop maize is of no importance in Borneo, and sago is only slightly so. According to Feuilletau de Bruyn,[205] this is because the sago palm grows by preference on the low banks along the rivers in the swamps. In the deeper places where there is much water this palm will not grow, nor will it do any better on the higher banks. Consequently in the Oeloe Soengei, the sago region where these palms not only grow wild but are also planted, is limited to the strip between Marabatan and Kabirau, along the Negara. This is one of the special cases of edaphic requirements, expressed in more general terms by Van der Laan[206] when he says: "The immense tropical rain forests of Borneo, mentioned many times in the past and down to the present time by many writers, but still never analyzed, may be characterized quite readily in the plant associations to be described which are closely related to the nature of the soil." The occurrences of the cocos in the small coastal strip of western Borneo, above described, is an exmple of how close the connection is between soil type and plant. Although the subject has not yet been adequately investigated this close relationship will undoubtedly also prove to be true for the various kinds of rattan, the different trees furnishing dammar resins, iron wood, etc. It will likewise be true for the introduced Hevea rubber.

The occurrence of certain crops, however, besides being connected with the soil and climate, is also dependent upon special factors as, for example, the race of men which cultivates the crop. Thus the Dajaks, beside predominantly upland kaiñgin rice, plant but few other crops, such as fruit trees and root crops. While the Malays, beside rice on the marsh paddie

205. L. c., p. 77.

206. E. van der Laan, Bosschen der Z. en O. Afd. v. Borneo, Tectona, XVIII (1925), p. 933.

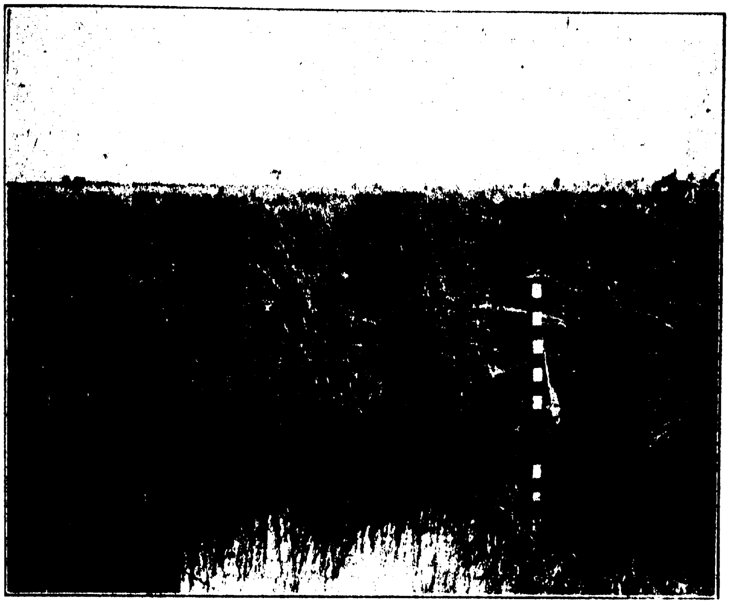

Photo by F. H. Endert

Fig. 155. Poeroen rushes (Fymbristylis diphylla) from which mats are woven, growing along the Siran swamps. Southeastern Borneo. On the subaqueous soil under this growth there forms but little peat. (See pp. 394, 402.)

plant rubber on the lower, slightly irregular foothills. The Chinese plant cocos on the coast, and also pepper (Piper nigrum) and gambier where the soil is good enough for them. They always plant relatively high value commercial crops, which require special care. With respect to crops which are really cultivated more like garden crops than as agricultural crops, such as in western Borneo the semangka (Citrullus vulgaris) (and that applies in a still greater degree to the laboe (Lagenaria leucantha)) the soil becomes ultimately so intensively altered into the condition which the cultivated plant requires that the nature of the original soil type used for these crops is a matter of relatively secondary importance. When such a crop, however, is cultivated upon a large scale, it often comes about that the natural factors of soil and climate do not cooperate. In Borneo tobacco, as is generally the case throughout the Netherlands Indies, is planted on a small scale by the villagers for their own use. Sugar cane, also is found generally in small quantities. But there are no large sugar cane fields. As an European plantation crop, tobacco had been raised in British North Borneo for more than half a century. Now its cultivation has been given up. Not only in Western Borneo but also in Southeastern Borneo cotton was also formerly planted; the cultivation of this crop has now

vanished. At present (1934) serious consideration is being given to the introduction of the cultivation of cotton in New Guinea. Although in the beginning for a few years it may perhaps go well and give hope of success, considering the points of very great similarity between Borneo and New Guinea, with respect to soil and climate, the prognosis for these plans cannot be favorable.

An example of a crop which not only occurs naturally on Borneo in the swamps, but is also planted, is the rush poeroen danau (*Lepironia mucronata*). It is true that this plant does not give any very high value product, but certainly it will hold its own, since the poeroen mats are made from it, and these as wrapping for bales of tobacco, go all over the world. Also poeroen tikoes (*Fimbristylis globulosa*) is found both wild and cultivated. From this rush finer mats are made. From ancient times these reeds have been at home in these subaqueous and relatively poor soils and in the future they will certainly continue to grow here.

* * * * *

Looking at the island as a whole, we come to the following conclusions: Except on a few, somewhat better portions of the land on and near to certain younger and older eruptive rocks in western Borneo in the Oeloe Soengei, Borneo in comparison with Java, Bali, etc., has naturally so very much poorer soil that in the near future it cannot produce enough grains such as rice and maize and other food crops to feed a dense agricultural population.

Borneo is a land of commercial crops, and among those especially the shrubs and trees--a land of extensive plantations, a region of forest products. The Javanese and Balinese are agriculturists and nothing more. The Malays in the first place are traders inured to the sea and in addition, without depending upon age-old custom, they plant whatever promises them some profit. It is for this reason that on Borneo but not on Java and Bali the natives have so rapidly gone into the cultivation of Hevea. In the future also the Malays and Chinese will raise what the world demands....cocos, gambier, pepper; and even though they may be very extensive cultures, forest products as rattan, iron wood and tengkawang will gradually come to be cultivated.

On the other hand Borneo's soil offers various possibilities in the domain of commerce, along lines in which on Java there may be little or no opportunity at all for development. Almost everywhere in Borneo under the allochthonous deposits along the big rivers can be found better earth than on Java for the making of bricks, roofing tiles and other terra cotta products. On Borneo, especially in the southeast are enormous quantities of iron ore. And when the technic for the preparation of liquid fuels, etc., from coal, lignite, and even from peat has been developed sufficiently, Borneo has limitless supplies of the raw materials.

In short, it seems to me that the time for the development of Borneo, even estimated roughly, lies far outside of these present times, and that first of all, commerce and industry must come into bloom before agriculture proper can obtain important opportunities. Was it not also the case in the Netherlands, that even after shipping and commerce had already been developed to a high degree that Betuwe and Groningen were still of no importance as agricultural regions?--It was the wealth obtained through commerce and shipping which placed agriculture in a position to develop an originally but fair to poor soil (in various respects to be compared with those of the plains of Borneo) to a height which can be paralleled in only a few parts of the world. In the Netherlands, for example, we use large amounts of commercial fertilizer. On the one hand this is an indication of the intensivity of the agriculture, but it is also indicative of the relative natural poverty of the soil. So there seems to be a possibility that in the far distant future Borneo will develop a great agriculture, even though this can only follow commerce and industry.

The south Russian peasant on his fertile black earth, the Egyptian fellah on his Nile silts which have been very productive for thousands of years, the Hindustani of Central India on the continuously productive "regur," and finally the

Javanese native on his soil which has been rejuvenated time and again by eruptions of volcanic ash are all representatives of static soil utilization. Alterations of the soil which mean progress arise from bitter necessity in those lands with poor soils. Will Borneo sometime outstrip Java? --Most probably the present generation will never answer this question.

* * * * *

BANGKA AND BILLITON

As regards their geology, their climate, the nature of their soil and vegetation these two islands so important for their production of tin are so strikingly similar that for our purposes they can without difficulty be treated together as one.

As shown by sheet IX of the Geological Reconnaissance map of the Netherlands Indies Archipelago[207] and the accompanying treatise by Van Es, there is also much similarity between these islands and large portions of Western Borneo, as for example, the surroundings of Bengkajang and Ketapang. Much of what has been said about Borneo could simply be repeated here, although considerable differences must also be taken into consideration. In any case the similarity justifies brevity here.

Soil-Forming Rocks

In contrast with other islands, we see in the map already mentioned and the adjoining sheet VIII, prepared by Zwierzycki[208] an unusually simple series of geologic formations. As it has been said "Bangka and Billiton with the surrounding smaller islands, consist of granite and a single sedimentary formation....which is composed principally of sandstones, quartzites and clay schists."[209] (Cf. Figs. 156, 157, pages 404, 405.)

The granite is "predominantly biotite granitite." That is to say: (1) Besides orthoclase (potassium feldspar), as a rule plagioclase (calcium-sodium feldspar also occurs. (2) The mica granitites are more widely scattered than the hornblende granitites. (3) Under the micas the dark biotite (iron magnesium mica) is much more common than muscovite (potassium mica).

The sandstones consist predominantly of quartz grains but sometimes also include fragments of schists or shales. With silica as a cementing material, and with transitional forms of silicious sandstones and sandy quartzites, they go over into real quartzites. Still the sandstones are not hard, that is to say, they easily disintegrate or break up. The quartzites are, on the contrary, very hard, for this reason they are not much attacked by weathering (especially in a climate as that of Bangka and Billiton with much cloudy weather and small temperature differences) so that the quartzites now stick up as steep peaks and mountain ranges above the surrounding sandstones and other rocks.[210] And in the cracks and crevices deposits of iron hydroxides are also found, as well as clay particles, which are the impurities occurring in the quartzites.

Depending upon the content of iron (brown iron ore) the clay schists or clay shales are light gray to dark brown in color.

In this mixed formation in the northern parts of both islands diabase also occurs in a very few places, as well as tuffs, the latter for the greater part silicified. For the formation of soils they are of as little importance as the few insignificant outcrops of crystalline schists which have been found on Bangka, though not on Billiton.

Since, except in perhaps a few occurrences, which then should be older, the granite has broken through the sedimentary formation. Along the contacts are found larger or smaller quantities of

207. In Jb. Mijnw. N. O. I. (1918), Verh. II. Prepared by L. J. C. van Es, Jr.
208. In Jb. Mijnw. N. O. I. (1929), Verh. Prepared by J. Zwierzycki.
209. R. D. M. Verbeek, Geol. beschr. v. Bangka en Billiton, Jb. Mijnw. (1897), Wet. Ged., p. 20.
210. Verbeek, l. c., p. 85.

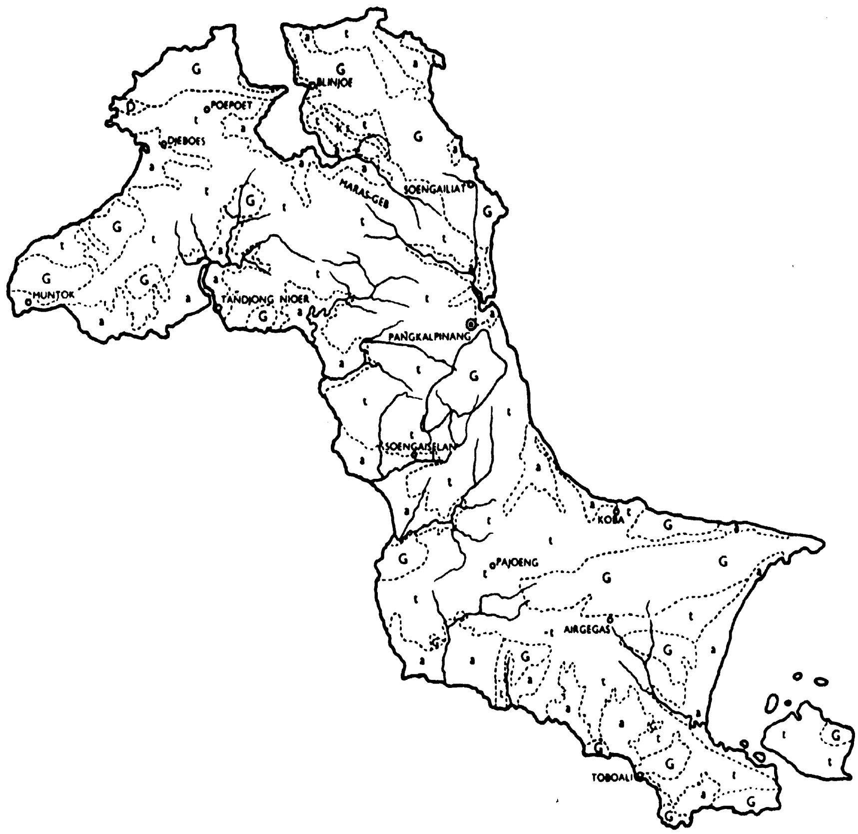

Fig. 156. Map of Bangka.

G = Granite
D = Diabase
Ks = crystalline schists
t = Trias = claystones, sandstones, etc.
a = alluvium = recent sedimentary deposits, etc.

metamorphic contact rocks such as hornfels. They are composed of quartz, brown and sometimes green mica, sometimes a little orthoclase, magnetite, and zircon. Since even originally these rocks possessed but very few constituents which weathering can affect and besides in a certain sense these rocks "have been hardened in the fire," they weather only with great difficulty.

Because of the great importance of the tin content of granites in tin mining, Verbeek has analyzed a number of samples.[211] But not a single complete analysis of a granite was made, neither then nor later. Nor have I been able to find a single complete analysis in the literature. Moreover, I have not been able to learn of the complete chemical analysis of any other rocks of either Bangka or Billiton.

Climate

Because of its uniformity the climate of Bangka and Billiton may also be handled very simply.[212] The islands lie between 2° and 3° south latitude, thus very close to the equator, and still farther west than Borneo, so that we may expect but little influence from Australia. Because of these reasons these islands have a

211. Verbeek, l. c., pp. 117-135.
212. Cf.: C. Braak, Het Klimaat van Ned.-Indië, II, pp. 133-145.

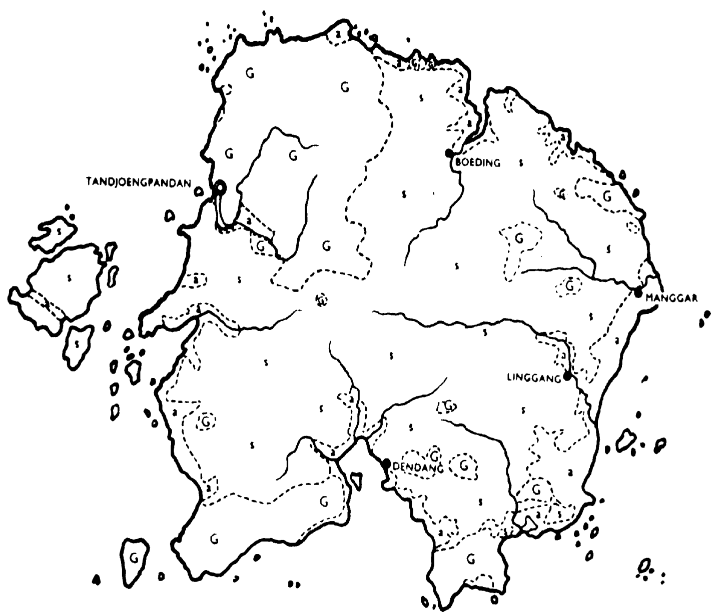

Fig. 157. Map of Billiton.

a = alluvium
G = granite, etc.
s = shales and other sedimentary rocks.

clearly equatorial climate.

On Bangka the highest mountain is but 700 m. high and on Billiton only 510 m., so that we would not expect these to have much effect upon the prevailing monsoon winds--certainly nothing more than a slight increase of the rainfall on the windward side.

At sea level the temperature averages about 26°C. From month to month the daily average does not vary even 1°. While in the course of each day the range is from about 23° at night to about 29° at midday. On and near the highest points of these islands all these temperatures are lower by about 3 to 4°, hence temperatures below 20° will very seldom occur, just as seldom as midday temperatures above 30°. But in the soil on bare, dark land such temperatures of course do occur. Yet because of the naturally increasing forest and its shading of the ground, taken by and large, no higher soil temperature than 25 to 27° need be taken into consideration.

The humidity of the air is high. At Tandjoengpandan, for example, the average relative humidity of the air is 89 per cent, varying from month to month between 87 and 91 per cent, and during a single day between 96 and 76 per cent. When exposed to the air table salt will practically always become liquid, and drying out of the soil can only occur where man has cleared off the forest, and even then only with difficulty, since on Bangka and Billiton it rains the whole year round. This is shown by the rainfall table (Table 88, page 406) compiled in the usual manner.

As may be seen from Table 88, on these islands there is not a single average monthly figure which is less than 100 mm. But of course that does not exclude the possibility that in some years there may occur "dry" months, indeed, sometimes there are a couple or even three such months in succession. So, while occasionally there may be times of drought, especially in localities toward the east and south, such as Soengeiliat, Pangkalpinang, Tǒboali, Manggar and Dendang, yet apparently such dry periods

Table 88

DISTRIBUTION OF THE RAINFALL THROUGHOUT THE YEAR ON BANGKA AND BILLITON

Station	(Location)	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall per year	Humid (wet) months	Arid (dry) months
Bangka																			
Muntok	West	about 10	52	149	423	286	311	251	182	130	102	107	107	191	313	504	2905	12	0
Djeboes	Northwest	" 20	43	171	424	240	264	293	267	185	176	199	216	288	392	522	3466	12	0
Blinjoe	North	" 15	43	169	400	190	226	276	245	185	168	152	183	240	357	482	3104	12	0
Soengeiliat	Northeast	10	43	142	291	171	198	183	172	154	136	113	111	157	210	318	2213	12	0
Pangkalpinang	East	about 20	43	156	296	219	254	230	185	147	135	112	124	160	224	316	2403	12	0
Koba	Southeast	10	42	138	260	159	228	257	203	185	147	134	144	175	241	258	2392	12	0
Toboali	South	6	43	170	235	191	233	239	286	218	158	138	111	206	262	273	2551	12	0
Pajoeng	South Central	about 40	22	177	338	280	363	326	281	196	130	138	164	272	305	332	3126	12	0
Soengeiselan	Central	12	29	179	288	243	309	301	218	220	162	192	219	261	297	302	3012	12	0
Billiton																			
Tdg. pandan	West	at sea level	52	183	280	167	198	268	246	180	170	139	169	271	363	416	2866	12	0
Boeding	North	"	43	169	355	181	261	349	296	219	187	140	152	245	366	432	3183	12	0
Manggar	East	"	51	160	307	205	264	229	252	202	164	124	102	159	245	357	2610	12	0
Dendang	South	"	51	146	254	175	241	243	256	176	143	109	111	187	282	316	2494	12	0

will not alter the general character of the climate which is "always wet."

Ways in Which Weathering Occurs and Resulting Soil Types

Beginning with the residual cases, it will be noticed in the first place that the rocks of Bangka and Billiton are not inclined to weather rapidly chemically. If such rocks were exposed in a temperate or cold climate they would probably weather little more than purely physically, that is to say, bursting and breaking down more or less into smaller fragments. But in the warm moist climate in which they actually are they most certainly do weather chemically, but relatively slowly. The consequence of this is that surface erosion can keep up pretty well with the weathering, so that no considerable thickness of residual materials can accumulate. In general, where the terrain has even only a moderate slope, the solid rock must lie quite close to the surface or even be exposed. Moreover the rocks are old, from the standpoint of weathering very old, and the alterations in their position as a result of tectonic movement also occurred in the very distant past. These are the reasons for the generally weakly sloping landscape forms (see Fig. 161, page 412). These are also the reasons for the relatively great areas of weathering material occupying secondary positions.

And it should be noted that not only by means of water flowing over the surface was that material moved from the places where it was formed. With the very long duration of the whole process on these two islands the phenomenon of "creep"[213] has played a more important role than in many other portions of the Archipelago. Especially for Bangka A. C. de Jongh[214] has drawn attention to this phenomenon. Under the influence of gravity, the weathering mass of loose, earthy material will move very slowly down over the sloping bed rock. But besides gravity there must also be some reason, a cause, for the soil to begin to move. Certainly the first factor in facilitating the creep is a greater or lesser degree of plasticity of the mass. While smaller portions of the soil remain homogeneous, yet the soil as a whole flows as if it were a thick syrup. But a loose mass, without plasticity, would not move in this

213. Through oversight the phenomenon of creep was not treated in the general Part I; this explains why the treatment has here been made somewhat broader than would otherwise have been the case.

214. A. C. de Jongh, Het ontstaan van waschertsafzettingen op hooge kanten en in valleien van het eiland Bangka, Alg. Ingen. Congres, (Batavia, 1920); 5e Sectie: Mijnb. en Geol., p. 15 ff. of the separate.

way. Periodical shrinking and swelling must occur to start the creep. Since the mass lies upon a slope, when the soil shrinks each part of the surface soil moves itself a minimal distance downwards. When the soil swells it is the subsoil which moves downwards. All parts do this equally, hence the whole mass moves gradually down the slope, while, as a whole, the several parts of the entire soil mass do not alter their positions with respect to each other.

These periods of shrinking and swelling may be daily, though they may be of longer duration, for example, annual. If they are caused by differences in temperature, then in the tropics they are obviously daily ones. While in higher latitudes there may also be an annual temperature period because of the differences between summer and winter. If however the period of shrinking and swelling is brought about by alternation of wet and dry seasons, then it is principally an annual period, although periods of much shorter duration, even daily ones may also occur. This last form of shrinking and swelling is dependent quantitatively to a high degree upon the content of colloids in the soil, combined with the plasticity and the force of cohesion of the particles. Thus it varies with the magnitude of that value which is well called "the shrinkage." For some kinds of heavy clays the linear shrinkage may amount to 20 per cent and more, for quartz sand it is zero. That the creep caused by the wetting and drying of quartz sand does not amount to much, while for loam and clay it is greater as the soil contains more clay is immediately obvious without any further discussion. At the same time, there are soils which do contain much colloidal material, but which lack the force of cohesion, such as iron-rich brown lixivium soils and which occur in considerable amounts on Java and Sumatra. Such soils show less creep and in blocks they also exhibit much less "shrinkage," (although upon microscopical examination they can be seen to be full of fine capillary cracks).

But the Bangka soil, residual upon granite, is indeed a quite heavy, slippery clay. And apparently the red iron oxide in it, which seems to be well crystallized goethite grains of around 1 mu diamater, has very little influence upon the character of the clay. Hence this soil must swell when it rains, and shrink when the weather is dry, and in consequence is subject to creep.

Where in the East Indian Archipelago do we find this phenomenon of creep most pronounced?--In just those places where the oscillations in water content of the soil are large, where the plastic soil material exhibits much shrinkage and swelling and in spite of high plasticity is still yet so porous that the water can penetrate deep into it. Thus heavy clay, which, for example, is flocculated by a high lime content, the effect of which is to markedly increase the permeability; such a clay is in marl clay and marl loam soils. On Java this soil type is known all too well and there that soil creeps so strongly that not only can the geologist demonstrate the phenomenon from a combination of indirect observations, but also every layman sees it with his own eyes, so that such soils are known as "sliding soils." They occur in a number of places in that Island where Tertiary formations are predominant, such as the northern part of Bandjarnegara, described in detail by Harloff.[215]

Later on when we are considering the soils of Java in detail we will come back to this special case, for the present we may be content with calling the attention of the reader to the following sentence from Harloff: "During the abnormally long dry season of 1929 the writer was struck by the fact that the bone dry uppermost layer, almost falling apart to a powder, moved downward more rapidly than the layer under it which was somewhat moistened by the ground water, even though this lower layer consisted of almost equally fine powder." --Harloff's explanation, however, which follows is not clear to me. It would seem that he has made it more complicated than necessary. Isn't it true that during this long dry season in the upper layers the creep downwards during the day must indeed have been considerable as also the contraction? But during the nights moisture came up as vapor from the deeper lying subsoil and was absorbed in the surface soil which had meanwhile cooled off. The consequence

215. Ch. E. A. Harloff, Over het kruipen van den bodem, enz., De Mijning. XI (1930), p. 96-101.

was swelling, again followed by creep, the latter again downward. During the following day the cycle was repeated. This is a beautiful example of "dry creep," intensified by the high water capacity and plasticity of the subsoil. One can picture to himself how after the first, continuous, heavy rains this dry creep was converted into visible "sliding" and slipping off of entire slopes!

* * * * *

On Bangka and Billiton the subaerial, chemical weathering of the granite proceeds in the following way: The orthoclase loses its potassium, which is replaced by hydrogen. After the intermediate stage in which there exist little scales of muscovite, the end result is kaolin. The biotite loses magnesium; kaolin and iron oxide remain behind. If amphibole be present, magnesium, calcium and ultimately sodium disappear, while iron oxide and eventually aluminum oxide are left over. Also the silicic acid is slowly carried away in the endlessly supplied fresh rain water. The smaller accessory minerals may, for the greater part, remain behind unaltered, scattered through the main mass of material which is a pale or somewhat brownish red to red, more or less heavy clay. For the greater part the quartz, too, remains behind unattacked, in irregular, sharp-cornered fragments, scattered throughout the entire mass. Freed from bases the pH of the clay falls to below 5.5. If from the vegetation some oxidized organic matter gets into the deeper layers of the soil, then the pH can become still lower, and under these amphibian or subaqueous conditions some iron becomes mobile. The compounds which move are rather the brown iron oxide hydrates with larger amounts of water, than the already dehydrated, red iron oxides. As a result, the surface soil becomes redder, the deeper subsoil becomes more flecked or veined with brown. In short--the picture is not very divergent from laterite formation already described on pages 143-145. Where iron concretions exist, bauxite nodules can also form. "Brown iron ore" is known to occur in many places on Bangka and Billiton. Verbeek[216] described bauxite nodules from Billiton, and I have obtained the same kind of nodules from the same island.[217]

Subaqueous weathering on Bangka and Billiton, as a result of the continuous, fresh additions of water, is equally effective in causing the granite to lose its bases, so that the residue from the weathering becomes more acid. Iron and aluminum oxide are likewise leached out and there remains a white layer of lixivium, on which is a humous, grayish layer and the profile is capped by a strongly humous, peaty black layer. The white layer is kaolin plus quartz, besides originally precipitated silicic acid (see Fig. 158, page 409).

Also on these islands large quartz prisms are found which are more than a decimeter in length and several cm. thick, and which appear on the outside as if they were strongly etched. And some do believe that the dull milk white outward appearance is to be ascribed to etching. How and when and where it could have taken place, however remains an open question. Others believe this dull rough surface to be the result of friction and slipping. But forms also occur which could hardly be produced in that way. For example crystals thick in the middle become thinner toward the outer ends with rounded faces, but still with the cross section remaining definitely six-angled. If this rounding off were the result of slipping, then it is difficult to see how the hexagonal cross section could continue to persist so well. But may it not be possible that the phenomenon is just the opposite, namely that the crystals have not dissolved away in the soil but that they have been growing? Has not perhaps fresh SiO_2 been deposited on the faces of the prisms from the acid aqueous soil solution? The dull surface would then be ascribed to the growing of the crystal in the surrounding clay mass which contained all sorts of irregular harder and softer portions, which would prevent the formation of smooth faces.

But however this may have come about, the final outcome of the subaqueous weathering is a mixture of quite pure

216. R. D. M. Verbeek, l. c., p. 175.
217. These are now in the collection of the Institute of Soil Science at Buitenzorg.

Photo from Billiton--Mij.

Fig. 158. Open pit mining of tin ore, Billiton. In the profile, at the left are exposed subaerial red and yellow layers, below which are iron concretions, then kaolin, meters thick, two layers of which are separated by a brownish yellow layer.

Photo from Billiton--Mij.

Fig. 159. View over the low hills (padangs) of Manggar and Samak, Billiton. Poor grass vegetation. (See page 410.)

kaolin and quartz in variable proportions, besides some tourmaline and still a few other minerals, of which the most important is the tin ore, cassiterite, which is not attacked by either subaerial or subaqueous weathering.

Regarding the kaolin on Bangka, it can also be said that for the greater part it is crystalline and consists of minute scales, often hexangular and of a diameter of from 2 to 40 mu. Analyses have already been recorded in Table 53, pages 159-160.

Among the sedimentary rocks are the sandstones. These for the most part consist of quartz grains and usually with silicious cementing materials, but sometimes however with a larger proportion of iron oxide as the cementing material. Upon subaerial weathering these rocks produce a sandy soil, which most times is somewhat yellow or yellowish brown from the iron, but apart from this element is a poor substratum for vegetation. When such a soil remains under subaqueous conditions, the sandy soil will also lose that iron through leaching. The iron is precipitated elsewhere as concretions, veins and layers. At many points, more frequently on Billiton than on Bangka, are found the so-called "padangs." These are slightly, elevated, flattish very weak lens-form bodies of sandy soil, which carry a miserable vegetation, "dry hard grass, or low scrub"[218] (see Fig. 159). However although it is an autochthonous weathering soil from an allochthonous sand bank, which once was a river deposit or a barrier beach, this is not an autochthonous weathering soil on sandstone. There is however some similarity between these various sandy soils soils. We must not neglect to mention that deeper in the profile of these padangs many times a layer impervious to water occurs. This horizon is called by the Chinese "fo sau kak," and consists of quartz sand cemented together by a dark brown cement composed of both organic matter and iron oxyhydrate.[219] It is clear that this deposit must have its beginning at the boundary of the ground water. In the deeper part of the padang, standing under water, where also even brackish water can be present the iron oxide dissolves and is then reprecipitated again in contact with the soil air, higher up in the soil profile. Traces of organic matter, carried downwards by the rain water, combine with that iron and accumulate.[220] Once shut off, the ore layer must grow upwards and fix with it all the iron carried down out of the yellow sand, while the conditions in the entire padang gradually change from subaerial into more subaqueous ones. The yellow sand becomes bleached to a pale gray sand and with much rain the padang becomes white. But because of organic matter the water is reddish in color, and where it is deep appears much darker, a coffee color to black. Hence the Malay name "ajer hitam" meaning black water.

Under the conditions on Bangka and Billiton the clay schists weather by taking up water again and reverting to clay or loam with more or less fine sand in proportion to the amount and size of quartz grains in the parent rock. The clay may be pale and and heavy, or browner and redder and then somewhat lighter, but always difficultly pervious. But thick layers of weathering soil never accumulate on it. Erosion from the surface and apparently also creep carry off much material toward the valleys and via the rivers to lower, flatter terrain. As this process has been going on for an endlessly long time, at present there are much greater amounts of the allochthonous clays and loams than of the autochthonous soil types. Subaqueous weathering under the influence of peaty water brings about a bleaching to sometimes a most extremely pure kaolin. It is then no longer possible to detect whether the material originated from granite, from clay schists or from both of them. In getting at the ore during tin mining, repeatedly enormous masses of snow white materials are exposed and washed

218. J. C. Mollema, De ontwikk. v/h eil. Billiton, enz. ('s-Gravenhage, 1922), p. 4.

219. Cf: Verbeek, l. c., p. 35-36 and 60-61. This is apparently the same type of profile as has been classified by the U. S. Bureau of Soils as a ground water podzol. In Pattani Province, southern Thailand (Siam) I have also found some examples of the same sort of profile. --R. L. P.

220. It is not entirely impossible that also a little dissolved lime in the brackish ground water in the subsoil also contributes to the precipitation of organic matter with the iron compounds in this horizon.

away. (Note the profiles exposed in Fig. 158, page 409.)

In the clay are found weak iron concretions, and also agglomerates of them, i.e., layers of brown iron ore. The latter however occur especially where from the beginning there was more iron, as for example in the neighborhood of the diabase occurrences in northwestern Bangka and northern Billiton.

Evaluation and Utilization of the Soil

If the reader has acquainted himself with the foregoing paragraphs, this question may have arisen: Can it be that there is still anything left of the soil of Bangka and Billiton to be evaluated and utilized?

It is of course undeniable that if these islands had not become of such great economic significance because of their wealth in tin they would not have attracted a bit more attention than similar regions of Borneo, Ceram, and New Guinea.

Both on Billiton[221] and on Bangka[222] repeated attempts to lay out paddies for cultivating lowland rice, have been pitiful failures. As Zondervan said 40 years ago, "thus the agriculture is mainly still limited to the raising of upland rice in kaiñgins." There are clearings which are planted during only one season and immediately thereafter again abandoned, and the land continues to lie idle for at least the 10 years following.[223] Field experiments carried out by the Agricultural Extension Service (1930) showed that moderate yields from kaiñgins average from 3 quintals per ha. to as low as 1.3 qu./ha. --while 3.5 to 4.5 qu./ha. is considered a very good crop! Verily a striking testimony as to the poverty of the soil (see Fig. 160, page 412).

It is, therefore, the more remarkable that on Bangka the cultivation of pepper (*Piper nigrum*) has gradually come to be important. But it must immediately be added that the cultivation of this crop is not to be ascribed to good soil, but rather to the fact that the pepper farmers or more exactly gardeners are Chinese, who are known to greatly excel all native peoples in this kind of work. This type of plantation crop (see Fig. 161, page 412) must also be included among the cultures of the Netherlands Indies which require the most capital.[224] On Bangka, except in the Muntok subdivision--"the good pepper soil is the predominating type, consisting of a bright yellow subsoil, on which is ordinarily a 10-30 cm. thick layer of surface soil which is darker and brownish. At a depth of from about 60 cm. to 120 cm. there is found a layer of red to reddish yellow little stones (iron concretions). The ground ought not to be too sandy, and at least at a depth of 40 cm. must have enough clay or silt so that the soil has a little plasticity. If the gravelly layer is lacking, then the soil is indeed still useful, but is valued at a lower figure. Above everything else the terrain must be always slightly sloping,"[225] so that standing water can never accumulate on it.

From this description by Rutgers it is quite clear that he is here referring to the older allochthonous sandy clay deposits, which have again been weathered, this time autochthonously and subaerially after their being exposed above water. It is presumed that this requirement of a layer of iron concretions at a definite depth is connected with an adequate water supply for the pepper roots of fresh aerated water from above.

Where the surface soil is thicker, darker, peaty, and this is the case on lower land, the ground water is not much below the surface. If pepper be planted on such soil the gardener is out of luck, for although in the beginning the vines grow luxuriantly, in about the third year they die off, before they have yielded any fruit. All the roots which extend deeper appear to be rotted off. Presumably the pH is too low.

The red, residual soil on granite (Muntok) is not suited to pepper culture. It would seem that the reason for this is

221. Mollema, l. c., p. 3; also: de Memories v. Overg. der Best. Ambt. upon their transfer.
222. H. Zondervan, Bangka en zijn bewoners., Ind. Gids 1893 en 1894, p. 165-166 of the separate.
223. Cf. Mem. v. Overg. Res. Hamerster (1931), p. 13.
224. A. Luytjes, De pepercult. op Bangka, Landbouw 6 (1930-'31), p. 862.
225. A. A. L. Rutgers, Meded. Labor. Plantenz. Buitenzorg No. 19 (1916), p. 10.

Photo from Billiton--Mij.

Fig. 160. Billiton. Unproductive kaiñgin of the Darats. Pepper garden in the distance.

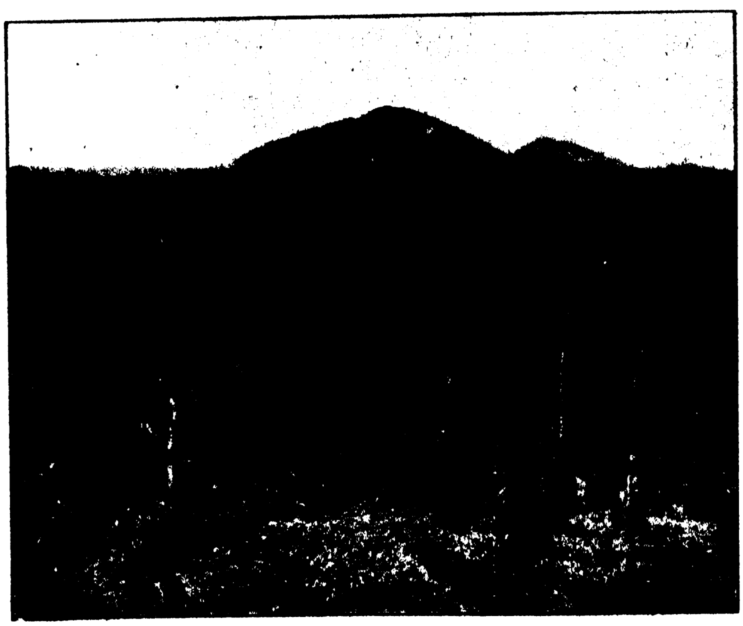

Photo by W. L. Utermark

Fig. 161. Bangka. Very intensively cultivated Chinese pepper garden on weakly rolling, allochthonous terrain. Neither on the forested granitic mountains nor in the too moist lowland soil is pepper planted. (See pp. 406, 411, and 413.)

not that the soil is too acid because of organic substances, but that it has been leached to an extreme degree so that it has too much strongly acid clay. Only very small amounts of plant nutrient materials are left in such a soil and those which it still contains are held very strongly by the clay; more than that, if plant nutrients are added to this soil as a fertilizer, these nutrients are also so firmly fixed that there are none available for the pepper. Moreover, this soil is too impervious to allow either the pepper roots to spread out adequately or to permit the movement of the soil moisture to the roots to make up for that which has been taken up.

On the other hand, the previously mentioned sandy clay soil can certainly be fertilized with success, for a large proportion of this soil consists of inert quartz sand. And in the cultivation of pepper heavy fertilizer applications are employed. In the excellent monograph by Rutgers referred to above we find various particulars, which at first sight seem strange, yet become understandable when the purpose is appreciated, which is to add plant nutrients, with particular care to avoid acids or the formation of acid. Some of the measures even give the impression that they are especially useful because of their action in eliminating an acid reaction which the soil may already have.

"The Chinese are thoroughly convinced that pepper cultivation without fertilization on Bangka is impossible," writes Rutgers,[226] "The most important fertilizer is 'tanah bakar,' burned earth. Since it is obvious that with the burning no new food comes into this burned earth, the only useful effect must be that an injurious factor disappears. This can be little else than--water, that is, the water which is fixed in the hydrogen clay, and which is the cause of the low pH. Since however the tanah bakar is prepared in a sort of heap in which there is much wood, above all else it becomes mixed with alkaline reacting wood ash. Hence, when added to the pepper soil, the tanah bakar undoubtedly makes the soil less acid.

Next to tanah bakar "the most important fertilizer is peanut cake. The gardeners also use shrimp scrap and fish scrap, as well as farm yard manure from both hogs and cattle." It is also very probable that both nitrogen and phosphorus are deficient in the soil. And it is worthy of note, according to Rutgers, that these fertilizers are not carried into the gardens fresh, but are first kept for a time mixed with water in cement vats especially constructed for this purpose. In some respects these tanks remind one of swimming pools. When ready the liquid is dipped out of the basins with little buckets and carried into the gardens where the vines are watered with it. Of course such a liquid must have an alkaline reaction because of its content of ammonia and amines. In this way no acid is added to the soil. On the contrary, the amount of any acid which is present in the soil is reduced.

These speculations are not based on any adequate number of pH determinations, but they give such a simple explanation of the facts that it certainly would pay for the trouble to test them experimentally. If this theory appears to be correct, then perhaps suggestions can be made as to how the same purpose may be achieved more cheaply, for example, through the use of coral lime, of basic slag, or of some potassium fertilizer, etc. In short--a closer study of this notable case of fertilizing opens apparently new perspectives in a somewhat different direction than the experiments of recent years with double superphosphate, nitrophoska, ammonium sulfate and potassium sulfate, for except nitrophoska these are all acid fertilizers.

After the above had already been written, there came to my attention a paper just published by Hardon and White,[227] which is a remarkable corroboration of the suggested explanations. Working on a series of samples of unburned soil, burned soil and burned soil mixed with ash, from a series of analyses they definitely proved that "as a result of the burning of the very poor lateritic sandy soil, which has a very far from saturated absorption complex,

226. **Experiments of the Agricultural Extension Service** (recorded in the Annual Report for 1929, p. 290) **show that** a certain number of vines fertilized produced 116 catties pepper, while an equal number of **unfertilized vines yielded** but 10 catties!

227. **H. J. Hardon** and **J. Th. White**, Gebrande aarde (tanah bakar), Landbouw X, 2, (1934), 49-75.

and reacts quite strongly acid, with a high degree of hydrolytic acidity and distinct exchange acidity, the base saturation markedly increased, the pH rose, and the hydrolytic and exchange acidity were significantly reduced." The plasticity was also reduced and "under normal circumstances an ultimately increasing stickiness disappeared."

There are a number of significant points in this excellent paper and they cannot all be repeated here, but since they apply not only to the soils of Bangka and Billiton but also to similar poor soils of Borneo and even of Java, they show that this piece of research has definitely solved the question.--

According to Hooyer[228] "in consequence of the poverty of the soil the cultivation of food crops by the native gives him only a very meagre return. In general the rice harvest is enough for but 4 to 5 months of the year." Rice must be imported from elsewhere and paid for by means of other agricultural products. Pepper already mentioned is the first and foremost of these. The inhabitants however also planted rubber and had a few years with good harvests, but by 1932 the culture of the trees was neglected and abandoned because of the low prices. The same thing happened with gambier. An experimental factory for sereh oil now stands idle; the cultivation of sereh has declined.[229] It is recorded that "in the environs of Tempilang, where the soil is still more infertile than the rest of Bangka," even kaiñgin cultivation has been given up.[230] In view of the previously recorded figures of yields this is comprehensible. About the widely distributed cultivation of cocos which are often a mainstay, Stein[231] wrote that "the cocos grow well, but bear practically no nuts." (Cf. pages 305-306.)

Taking all the above together, we arrive at a depressing conclusion, that all of Bangka and Billiton depend entirely upon tin mining. Whenever that is finished so that the inhabitants can no longer obtain their entire support from it, or at least a supplementary income, then these islands will no longer be able to maintain the present number of inhabitants. It is already the case that it requires 2.5 ha. per year of kaiñgins to support one person. That is, with a rotation time of at least 10 years, but preferably 15, an area of from 25 to 40 ha. per person would be necessary for "a very modest supply of food, for a period of 4 to 5 months." That makes one pause and think of the future, and how it will be necessary then, as already now is the case in the lean years, that the Chinese in large numbers ought to leave voluntarily or be sent away from the tin islands. The need of food by the inhabitants would compel an exodus to more favored regions, as a result of which the populations of 17.4 per square km. (Bangka) and 15.1 (Billiton) would fall to 2 or 1 inhabitants per square km. as at present is the case in large portions of Borneo and New Guinea.

As we conclude this discussion of Billiton and Bangka, mention might merely be made of the richness of these islands in earths for industrial purposes, in particular for ceramics. Throughout the research in connection with prospecting for tin it has been demonstrated that both islands "possess inexhaustible quantities of excellent kaolin."[232] "Beautiful, white quartz sand occurs on Billiton in large quantities"; and there are similar quantities on Bangka. Pegmatite, unfortunately is found only in a few, small, economically unimportant lenses. This feldspar in adequately pure condition is not available in quantity. Bauxite is found in sporadic knolls; larger quantities occur on the islands on the Riouw Archipelago.

Up to the present time neither the kaolin nor the quartz sand, nor the fire clay have been worked in commercial quantities. It is however difficult to believe that sometimes in the future this will not be undertaken.

In conclusion, it is as if nature developed a peculiar "either....or." In those places where the soil is particularly

228. D. G. Hooyer, Verv. Mem. Overg. Bangka en Ond. (Mei '31), p. 9.
229. Stein, Mem. v. Overg. Afd. Muntok (April, '19).
230. J. Wentholt, Mem. v. Overg. onderafd. Muntok (Nov., '28).
231. Stein, Mem. v. Overg. Afd. Muntok (April, '19).
232. H. W. de Vriendt, Vuurvaste klei op Billiton (De Ingenieur, 1920), no. 28, pp. 506-507.

fitted for agriculture, as a rule there is not much doing in the field of mining (Java, Deli, the lake region of the Celebes, Minahasa) but where mining comes into the foreground there is, as a rule, not much agricultural value (Bangka and Billiton, the Indian coal and gold districts, the Verbeek Mts. and the iron ore regions of southeastern Borneo, Martapoera, etc.). This applies not only to the Indies, but actually for the entire world. While although the newer technics which make it possible to obtain valuable mineral products from great depths (petroleum, coal, salt and sulfur) somewhat blur that picture, yet even today a region or district is either mainly agricultural or is mainly a mining and industrial region, and only very exceptionally is it good in both respects. This is also, by nature, the case with the different islands of the Netherlands Indies Archipelago, and different parts of them, as pointed out, where each supplements and assists the other with raw materials and helps to form an organic whole!

In some respects Sumatra is very similar to Borneo and New Guinea. From this standpoint it would certainly be desirable to consider the soils of Sumatra as a whole.

In certain other respects, however, Sumatra is distinctly different, particularly as a result of the volcanic activity. In some localities there are very great differences in the soils, which make parts of Sumatra much more like Celebes and Java. Hence it is preferable to deal with Sumatra, region by region, for each really needs separate consideration.

The contrasts which are here indicated may make clear why there are in the beginning general chapters dealing with the soil-forming rocks and the climate. In separate chapters there follows a more specialized and detailed treatment of each of the different parts of Sumatra. This is especially necessary to bring out the special features of the soils--their origin, their characteristics and above all their utilization. It is true that considering the subject in this way does not entirely exclude repetitions, but they will be limited in length and few in number.

The Soil-Forming Rocks of Sumatra

In the course of the geological history of Sumatra, time and time again igneous rocks have appeared at the surface. From the moment that they appeared they were attacked by weathering and erosion and themselves became the materials which were deposited as sediments, which later became hardened and finally altered into sedimentary rocks.

Where, however, these magmas reached the surface of the earth, not as viscous flowing lava nor as already solidified, massive (plutonic) rocks, but as broken up blocks, bombs, gravel, ash--in short as fragmental ejecta thrown into the air and by this route came to the earth, then, even before they were weathered by wind and flowing water, they were being carried away and were promptly deposited as sediments. Beginning from that instant they joined in the processes forming the sedimentary rocks. On Sumatra that has been the case on a very large scale, a process which is still taking place today.

In general, however, we can certainly say that the older the sedimentary rocks are, the more they have been changed by all that they have been through since their formation, so that in many cases it is today difficult to say what the sediment originally was from which the materials had originated, and still more difficult to say what the parent rocks were from which that sediment came. With all this we are getting into more properly petrological and geological problems than into problems within the scope of this book. In this study we are more concerned with what these rocks now are, of what minerals they now consist and, consequently, how they will behave when subjected to weathering, erosion, and soil formation.

But in the younger and youngest sedimentary rocks frequently one can still distinctly recognize the yet pretty well unaltered mineral and rock components of which the original sediment was composed. This greatly facilitates deduction by analogy as to how the weathering must go and which weathering products must originate from it. In these respects Sumatra is rich in striking examples.

* * * * *

If it were not first necessary to devote a few words to the development of the knowledge concerning the soil-forming rocks of Sumatra, at least in so far as this has been stated in words and delineated on maps, and especially the various stages through which the development of this knowledge has passed, we should at once proceed to a general discussion of the soil-forming rocks of this island.

For such a great region it is obvious that a beginning in the study of the

geology was made with local observations at different points, from which the geologists exterpolated and generalized. At the beginning of this century there was still prevalent this idea which is general rather than particularly geological: "Java is now well developed; that is, it is getting on well. Now it is Sumatra's turn, for this island is exactly the same sort of land, with volcanoes and all such; it is only waiting to be unlocked and worked." Later it was clearly recognized that while this idea was not entirely wrong, it was still only partly correct.

The occurrence of important minerals such as coal, petroleum and gold, was the reason why Sumatra, in the course of a number of detailed investigations, was studied geologically more fundamentally than even Java had been.[1] About twenty years ago the Exploring Service of the Department of Mines began to unify the scattered data and to issue the material in one series of publications: the Geological Reconnaissance Maps 1:1,000,000 for the Entire Archipelago, with accompanying letter press text; Sumatra was spread over 5 of the 21 sheets. The sheets of this series were not issued all at once, but are appearing from time to time, 8 sheets have still not yet been published, though all five[2] relating to Sumatra have appeared.

It was all too quickly apparent that these maps were not adequate. On the one hand, because of the small scale of 1:1,000,000 (on this scale the Netherlands would not be as large as a single page of this book) which compelled the omission of all the important details. On the other hand because in the compiling of the maps so many uncertainties, gaps, and even inaccuracies cropped up that it was necessary to start on a new project from the ground up.

Hence in 1927 in the extreme southeastern corner, in the Lampongs there was begun the new "Mapping of Sumatra." The first sheets, on a scale of 1:200,000 were published in 1931, at the time of writing (1936) ten sheets had been issued. Upon comparing this new series of maps with the former series, one is immediately struck by the much more detailed differentiation of the rocks, which, for our purpose is of great significance, and for which we are very glad.

In connection with the only slowly growing knowledge of the rocks of Sumatra, it stands to reason that in the beginning the eruptives were only broadly differentiated, at any rate on the maps they were many times grouped under one color, and under one name. Thus in the legend of his Reconnaissance Map (Sheet 15) Van Es (1916) uses only the one word "volcanic," while Zwierzycki on sheet 7 (1919), in addition to older andesite and basalt, mentions only "andesitic effusives." On Sheet 1 (also issued in 1919) there were besides "older andesite, basalt and melaphyre," also the "liparitic effusives" of the region around the Toba Lake indicated, and in addition "andesitic effusives" were differentiated. But on Sheet 8 (1929) "andesite and basalt," and "dacite and rhyolite" were separated, yet all the others--basic or acidic, coarse or fine, quite fresh or quite a bit older were grouped together under "volcanic tuffs." As to this Zwierzycki himself says:[3] "The most important rocks are of andesitic origin, they are layers of lava, breccias, sandy tuff deposits and tuff clays." (It seems to me tuff loams would be a more suitable word for this last group. --E. C. J. M.) "Locally basaltic, dacitic, and liparitic tuffs also occur, but in the literature which has been consulted the statements are so indefinite and of such local character that the distribution of the different types on a map cannot be given even provisionally." This statement makes it abundantly clear why even on the 1:1,000,000 map of 1929 only a single orange-red color includes all the above grouped-together

1. Compare: L. Rutten, Voodr. geol. N. O. I. (1927), p. 343-353.
2. Sheet I. Jb. Mijnw. N. O. I. (1919), Verh. I, J. Zwierzycki: Noord-Sumatra.
Sheet II. Jb. Mijnw. N. O. I. (1925), Verh. II, J. B. Scrivenor, A. Chr. Bothé: Bengkalis, Malacca, Riouw-Archipel.
Sheet VII. Jb. Mijnw. N. O. I. (1919), Verh. I, J. Zwierzycki: Pad. Bovenlanden.
Sheet VIII. Jb. Mijnw. N. O. I. (1929), Verh. I, J. Zwierzycki: Djambi, Palembang, N.-Lampongs.
Sheet XV. Jb. Mijnw. N. O. I. (1916), Verh. II, L. J C. van Es: Z.-Lampongs.
3. L. c., p. 109.

volcanic products. But at the same time the Geological Service, being mindful of the many things found to be lacking in these "Reconnaissance Geological Maps of Sumatra," under the direction of Zwierzycki commenced with great diligence the new mapping of Sumatra.

We should not have tarried so long over this little bit of history if there had not been connected with it a reversal of certain general conceptions, at least in my own mind. As has already been said Zwierzycki wrote in 1929: "the most important rocks are of andesitic origin." But now, however, in so far as maps of the new series covering South Sumatra are at hand, I cannot free myself from the impression that at least in South Sumatra, acid, pale eruptives occupy an area at least as large as do the andesites, especially if we include with these the so-called Upper Palembang strata which also, for a large part, consist of such acid and pale tuff material. If one thinks further of Djambi and the "Sub-Barisan Plateau" belonging with this, then the chance is very good that once the new mapping has been carried through to this region, it will establish that there also the eruptives are on the acid rather than on the basic side. If this be the case dacites, liparites, and rhyolites besides their superficially distributed tuffs, will win over the andesites and basalts and their tuffs.

A phenomenon such as black pumice stone, so common in East Java (Lamongan, Raoen), Bali (Batoer), the Minahasa (Sopoetan) etc., only seldom occurs on Sumatra. As a rule the Sumatran pumice stone tuffs are very pale and always possess more or less free quartz as crystals.

In the Padang Highlands only with difficulty can we call basic the pale tuff rich in pumice stone of the plateau of Agam and the Karbouwen ghat (see Fig. 18). The tuffs of the Batak Lands are almost exclusively pale and liparitic. According to the verbal communication of Dr. Druif, on Sumatra's East Coast the liparitic tuff covering extends out much farther toward the south-east than is shown on Reconnaissance Map No. 1. While from the investigation of this region it also appears that "the Deli mountains" furnish almost no andesite, but rather principally dacites. Also along the Gajoe road we again find pale tuff and rocks rich in glass, indicative of their poverty in iron. In short, it remains to be proved whether for Sumatra as a whole, andesitic rocks (or basic rocks) really are the more important, at least as to the area exposed at the surface.

Even a glance at the orographic map of Sumatra shows immediately how along the whole length of the island, from northwest to southeast, there runs not one single mountain chain, but rather a single relatively narrow strip of mountainous land, with low land on both sides. On the west side this low land is mostly narrow or even almost lacking and repeatedly interrupted, while on the east side the lowland is broad to very broad. It was determined roughly that of the entire area of Sumatra including Bengkalis, but excluding the islands of the Riouw Archipelago, the land more than 100 m. above the sea amounts to approximately 40%, and thus the low land, between 0-100 m. is about 60% of the total area.[4] This lowland is for a very large part "alluvium." That is it has been carried out as sedimentary deposits, which in part are still being formed. But another part consists of the river deposits of an earlier time, now already again autochthonously weathered and altered. It is true however that in a number of places in the so-called mountainous land above the 100 m. line there are valleys partially filled with alluvium.

Therefore we should not take the above-mentioned differentiation into mountainous land and lowland as giving more than very roughly the area on the one hand of the higher land of the soil-forming rocks which is being "carried away," and on the other hand the area of the low land, which is receiving the deposits of sediment and is becoming more or less built up and (especially along the coast) gradually growing outward. Subsequently we shall see where these general considerations do not apply quantitatively. Meanwhile, without making any serious mistakes, we may look to the Barisan Mountain Ranges (taking this name in the general sense) as the source of all the Sumatran mineral soil material.

* * * * *

4. This was done by drawing the map on a uniform sheet of paper, cutting out and weighing all of Sumatra, and then that portion of Sumatra within the 100 m. contour line.

In the Barisan mountains there are Pretertiary, Tertiary, and Quaternary, including Recent, rocks. Igneous rocks occur in all three groups.

To here subdivide in detail the Pretertiary formations would be of little significance; for our purposes the following will suffice: Crystalline schists, of which the reader has already learned of great expanses on Borneo, Celebes, the Moluccas and New Guinea, play practically no role on Sumatra. Except a couple of spots in Benkoelen, out along a line northwest from the Ranau lake, thus far there are known only two respectable occurrences of such schists. These are in the Lampongs, the first along the railway and to the north of the Wai Sekampong, west from the line, and the sec nd a much smaller body east from Telok Betong bay.

An extensive complex of sedimentary rocks, considered to belong to the Permocarbonate, and which is found from extreme northwestern Atjeh to as far south as Djambi, consists of slates, gray and black, shining and dull, here and there with quartz lenses. Silicious slates, quartzitic sandstones, graywackes, and masses of conglomerates also occur. Two influences have brought about facies modifications:

1. Lime inclusions in the form of compact limestones in thin layers, and also in massive formations, presumably derived from coral and Bryozoan reefs. The limestone is sometimes dolomitic, and sometimes (where it lies close to granite and diorite) it has been altered by contact metamorphosis into crystalline limestone (marble).

2. Volcanic interludes, which are responsible for layers or covers of andesite and porphyrite, and also melphyre and diabase between the first-mentioned layers, as well as the accompanying tuff sandstones, conglomerates, and breccias. As a result of contact metamorphosis with nearby younger granites and diorite, all sorts of other rocks such as hornfels, phyllite, talc, and chlorite slates and serpentine schists have originated.

It is apparent that the whole is a very varied complex of rocks, of which, however, as a whole, neither chemical nor quantitative mineralogical analyses have as yet been published.

Above this complex of Permocarbonate rocks are similar Mesozoic deposits, which have been indicated on the geological map under Trias, Jura, and Krijt. These formations consist of shales or mudstones, quite fine-grained quartz sandstones, marls and marl shales, thin bedded limestones, etc. These rocks are found less often in Northern Sumatra, more generally in Central Sumatra (especially in Djambi and Upper Palembang), and almost never in Southern Sumatra.

Among the igneous rocks of the Pretertiary we should first mention the granites, which are found very widely distributed over pretty much all of Sumatra. "They are relatively acid transitional rocks between granite and diorites, characterized especially by biotite and hornblende.[5] The granites are in part classified as older than the Permocarbonate, another part however as younger. But that makes little difference in the composition. --Pretertiary andesite, diabase, etc., have already been mentioned above.

The Tertiary rocks form the second large group; these are divided into the Paleogenic and the Neogenic.

The Paleogenic rocks consist of layers of breccia and conglomerate in which occur large blocks of the solid rocks at that time present in the mountains already mentioned above. Upon them are many quartz sandstones, brown, yellow or gray; and then black or gray clay shales. Occasionally coal occurs locally, elsewhere limestone. The principal constituent of all these rocks is quartz. The Paleogenic rocks occur over a great area in Northern Sumatra, and also in Central Sumatra, but very much less to the south of the Batanghari. It is by no means improbable that more to the south there are also Paleogenic rocks, where they have been deeply covered first by thick layers of Neogenic deposits, and these in turn have been covered by younger volcanic deposits.

The Neogene sediments are also found somewhat farther away from the central mountain range than the Eogene; but also in strips parallel to that formation, though it is also with interruptions. Stated in a better way: here and there they are hidden by a covering of younger volcanic

5. J. Zwierzycki, Toel. blad VIII, Jb. Mijnw. (1929), p. 108.

eruptives. In Djambi these Neogene sediments are the broadest and there alone occupy an area greater than that of the entire Netherlands. They are not everywhere of the same composition, but still almost everywhere in Northern Sumatra they include clay marls with a large proportion of Globigerinas and marly limestones. In the lowest layers less true sandstones occur but they are more frequent in the higher ones. In Neogene time the volcanoes gradually became more and more active, and just at the end of that period their activity was at the maximum, so that in the layers being deposited near volcanoes, the higher the layers the richer they are in tuff. Hence, in Palembang and also even in Djambi the following differentiations may be made: (1) Lower Palembang strata, around 1,500 m. thick, consisting principally of shales, in which are localized masses of sandstones, and also even thin limestone layers. (2) Middle Palembang layers, about 600 m. thick, in which is quite a good deal of eruptive material of a relatively acid nature, with quartz crystals; above this many layers of lignite. (3) Upper Palembang layers, certainly more than 600 m. thick, consisting principally of acid volcanic tuffs.

From this and from a number of more detailed descriptions it appears: (1) All the Neogene was deposited during a rising of the land, thus with a gradually decreasing depth of the sea and finally by land deposits. (2) Southern Sumatra was exposed above the water earlier than Northern Sumatra, the consequence of which was that the Neogene deposits in Southern Sumatra, earlier and to a greater degree, took on the character of land sediments; and (3) in the south the volcanic activity was stronger and more general than in the north where it continued to be more localized, although in a very wide region about the Toba lake one must admit that volcanic activity of the greatest intensity occurred. For this reason in Northern Sumatra more Preneogene formations remain exposed.

As to the nature of these important volcanic eruptions: At the beginning of the Neogene the intermediate to acid rocks, andesite, dacite, and liparite flowed out, or, as fragmental ejecta, were blown into the air. Later the eruptions were principally liparitic and then in the beginning of the Quaternary when the general activity began to lessen, the volcanoes again erupted more and more dacites and andesites. Even basalt was erupted at a few points.

In the first part of this book the results of a number of analyses of Sumatran rocks have been given. Since that portion of the book was written new analyses have appeared in the explanatory statements accompanying the South Sumatran sheets of the Geological Survey. For that reason, when we consider the mountainous regions of South Sumatra a table of these new data will be included and will be discussed in some detail.

The Climate of Sumatra

The equator crosses the middle of Sumatra, just as it does Borneo. Hence one should be inclined to expect for this island just as uniform an equatorial climate. And for Central Sumatra that is the case, but not for Northern nor Southern Sumatra. Sumatra lies between 6° North Latitude and 6° South, and in such a way that the northwestern point extends toward Asia, while the southeastern tip is close to Java, and consequently likewise comes within the influence of Australia. This means that during the winter of the northern hemisphere (December to March), dry winds from Asia extend their influence, though it may be weak, down into Northern Sumatra, while during the Southern Hemisphere's winter (June to September), the influence of the dry east monsoon reaches southern Sumatra.

The high Barisan mountain chain confines these influences to that portion of Sumatra east of these mountains. Thus, though the rainfall may vary more or less along the entire western coast, droughts are really not known there. In the west monsoon the rain is heavy; in other times somewhat less heavy rains occur. But along the entire west coast there is not a single rainfall station with a considerable number of years of observations where any of the monthly averages of the year are less than 100 mm., and the most lie above 150 mm. and even above 200 mm. (see Table 89, page 421).

Upon studying these figures more closely the two influences which have

Table 89

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA[1]

I. Along the Western Coast, close to the sea

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Lho'nga.....	at sea level	31	138	166	127	167	140	263	185	205	230	313	293	234	200	2523	12	0
Tjalang.....	"	23	176	236	172	229	296	383	294	324	316	406	464	357	232	3709	12	0
Meulaboh....	"	35	170	261	247	318	389	285	220	278	258	350	443	371	345	3765	12	0
Tapatoean...	"	28	170	296	238	330	343	259	192	199	215	280	356	357	313	3377	12	0
Singkel.....	"	40	188	299	281	363	456	368	281	280	375	405	567	514	387	4576	12	0
Baros.......	"	15	137	331	245	366	294	231	190	200	250	302	387	400	331	3607	12	0
Sibolga.....	"	51	208	374	330	434	450	344	263	284	330	371	505	502	419	4606	12	0
Natal.......	"	16	146	255	187	313	318	241	180	277	323	304	452	446	396	3692	12	0
Aerbangis...	"	47	154	231	204	263	313	203	161	171	238	245	353	346	340	3068	12	0
Priaman.....	"	24	157	314	202	334	325	247	195	180	242	305	456	488	410	3707	12	0
Padang......	"	52	191	349	259	307	363	319	308	277	351	410	505	515	485	4448	12	0
Bainan......	"	31	143	339	253	309	270	221	162	164	245	292	378	401	367	3401	12	0
Balaiselasah	20	15	129	310	240	289	276	190	152	171	210	299	320	381	286	3124	12	0
Moekomoeko..	at sea level	28	140	293	214	254	258	193	150	180	211	327	382	418	373	3248	12	0
Lais........	"	19	143	300	240	276	279	218	153	152	245	291	355	388	316	3213	12	0
Benkoelen...	"	52	166	297	269	285	283	234	188	176	210	247	358	382	350	3279	12	0
Manna.......	"	15	169	270	269	304	219	217	148	239	395	510	527	446	389	3933	12	0
Bintoehan...	"	16	137	301	255	266	196	189	139	193	233	352	386	437	324	3273		
Kroë........	"	28	145	310	267	284	269	243	181	173	195	256	373	404	341	3296	12	0
Koto Agoeng.	"	18	155	200	214	172	174	175	133	195	310	311	401	327	254	2866	12	0
Poetihdoh...	10	18	140	266	209	182	184	183	135	141	212	259	406	368	272	2817	12	0

1. Again as usual, the figures are from Meded. 24 of the Kon. Magn. Meteor. Obs. to 1928, to which the data of 1929 and 1930 have been added. The same is true for all the following tables.

already been mentioned can be seen. Even more evidence of them may be detected in Tables 93 and 94, pages 424 and 425 for Sumatra. (Note particularly Lho'nga in the north and Semangka bay in the south.) Moreover the annual figures lie between 3,000 and 4,500 mm. and most of the monthly averages (around 72%) lie between 200 and 400 mm.

Up against the Barisan chain there is the same rainfall type, though as a rule more strongly developed because of the deflection upward of the winds. In that region there are fewer larger towns, as is obvious, since there will be leaching of the cultivable soil, heavier erosion, hence, worse agricultural conditions, and thus also fewer rainfall stations. Typical of these conditions are the data in Table 89, above.

With a total rainfall of between about 3,500 and 6,000 mm. there is almost no monthly average of less than 150 mm. and more than half the monthly totals fall between 300 and 500 mm. and even a considerable number between 500 and 800 mm.

Behind the first, most westerly chain of the Barisan, and particularly where there are several parallel chains, long narrow valleys are to be found. In general these are reached only by descending winds, hence the rainfall is suddenly strikingly less. It is still not so low as it is at such places as Makassar or elsewhere in the eastern part of the Archipelago. Therefore there is no drought period alternating with a season of heavy rainfall. There is, rather, a quantitative decrease throughout the whole year. As appears from Table 91, page 422, in the valleys referred to, and especially in basins which are surrounded on all sides by mountains of about the same elevation, and particularly in Central Sumatra, we find the lowest rainfall figures. Annual figures of not even 2 m. at stations with elevations of more than 200 m. and with monthly figures for June to August, being for the greater part below 70 mm. are thus on the arid side, while no single monthly average exceeds 300 mm. That is indeed very strikingly different from the picture which we get

Table 90

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

II. On the slopes toward the sea, behind the West Coast

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Pintoebosi......	1150	12	215	356	300	329	385	255	120	143	174	314	358	329	328	3391	12	0
Pinangsoreh.....	46	22	176	333	267	361	408	300	215	211	347	350	521	446	404	4163	12	0
Anggoli.........	90	19	170	351	300	420	409	297	222	222	312	362	505	504	443	4347	12	0
Moearasoma......	500	16	180	334	277	325	449	247	142	216	273	354	433	497	357	3904	12	0
Loeboekbasoeng..	105	25	142	365	226	317	354	292	176	208	284	364	415	468	378	3847	12	0
Singgalang-top..	2877	13	---	366	273	315	327	229	180	189	191	339	375	427	423	3634	12	0
Kajoetanam......	144	32	164	548	393	503	540	390	274	235	351	434	555	627	600	5450	12	0
Loeboekselasih..	1000	51	209	332	227	237	306	235	169	165	229	308	393	435	429	3465	12	0
Indaroeng.......	250	20	165	510	376	536	556	467	360	325	433	557	677	715	637	6149	12	0
Oeloelimaumanis.	187	7	234	422	349	307	472	309	344	349	440	485	546	489	633	5145	12	0
Lebongtandai....	180	23	234	503	397	441	577	471	375	307	515	536	702	581	478	5883	12	0
Tandjongsakti...	490	21	240	460	311	384	420	297	182	169	167	229	239	446	488	3884	12	0

Table 91

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

IIIa. In long narrow valleys, basins, and on plateaus, behind the first Western Barisan range.--Total less than 2,000 m.

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Takengeun......	1205	25	157	162	123	184	169	116	66	63	83	142	202	226	237	1774	9	0
Blangkedjeren..	840	24	146	143	112	198	182	138	74	53	86	126	198	229	196	1735	9	1
Laubalang......	220	19	131	129	109	166	184	120	57	49	72	119	172	183	178	1538	9	2
Balangdoewa....	610	18	136	142	114	179	208	130	61	67	88	140	208	201	195	1733	9	0
Kabandjahé.....	1208	20	143	158	102	158	173	124	66	47	91	137	203	216	204	1680	9	1
Seriboedolok...	1418	21	156	153	103	177	169	128	84	63	98	145	216	193	215	1744	9	0
Perapat........	920	13	133	162	126	198	210	117	67	44	68	176	249	247	191	1855	9	1
Pangoeroeran...	900	19	132	155	155	172	176	121	64	43	63	110	162	160	169	1550	9	1
Mogang Palipi..	910	9	147	202	168	197	161	107	61	34	46	141	197	231	177	1722	9	2
Doloksanggoel..	1451	12	173	187	128	163	267	120	58	63	64	163	229	288	213	1943	9	1
Sipirok........	898	14	141	172	127	156	190	116	74	60	79	158	177	172	158	1639	9	1
Pidjarkoling...	200	13	127	209	120	165	164	96	56	60	69	168	249	300	189	1845	8	2
Penjaboengan...	222	16	121	154	93	151	140	112	61	62	95	138	178	190	157	1531	8	0
Ampang Gadang..	284	16	83	230	111	124	122	66	60	38	46	102	158	168	164	1389	8	3
Kota Tinggi....	750	19	163	173	127	159	165	130	76	69	92	164	199	232	180	1766	9	0
Soeliki........	554	8	140	169	148	141	180	137	76	45	100	195	256	249	178	1874	10	1
Padangtarab....	705	15	100	223	133	159	202	123	67	47	94	148	159	151	155	1661	9	1
Boeo...........	260	16	120	225	153	159	193	120	86	59	119	200	251	224	149	1938	10	1
Koemanis.......	220	8	145	203	149	132	176	87	72	51	68	125	160	196	144	1563	8	1
Tdg. Ampaloe...	200	8	141	183	111	145	166	102	57	53	57	113	156	206	139	1488	9	3
Singkarah......	365	17	99	168	95	153	168	107	68	58	94	111	146	125	171	1464	9	1
Soempoer.......	490	19	112	175	156	135	174	114	56	55	81	126	156	166	178	1572	9	2
Soengeipenoeh..	630	21	145	211	155	171	241	133	136	100	145	145	183	197	163	1939	12	0
Padanggelai....	500	10	162	235	138	111	101	63	60	42	22	73	110	144	145	1244	7	3

from Tables 89 and 90, pages 421 and 422.

As to what the soil indicates, we shall seldom or never be able to observe so severe a drying out that the weathering form will be changed. Because a continuous drought of 3 months or longer is an exception and by no means an annual phenomenon, with an annual rainfall of no more than about 1.5 m. the soil just under the surface practically always remains "continuously moist or wet." It should also be mentioned that the other 9 months almost always have more than 100 mm. rainfall.

Moreover the extent of these relatively dry areas is but small. There needs to be only a small break in the surrounding mountains through which ascending wind from the sea, be it from the east or from the west, can get into the basin or valley, when the rainfall clearly increases, as Table 92 shows. The annual average is but ½ m. higher, yet the arid months have vanished and the most generally occurring monthly average which in Table 91 lies between 150 and 200 m. is here higher, lying between 200 and 300 mm. Also much higher figures are almost never found in Table 92. Only Loeboe Sikaping occupies a special place in it, although the station is located in a very definite long narrow valley. In the west the Taloe mountains are only about 1,000 m. high while in the east they are more than 2,000 m.; the west wind is forced up much higher by this steep ridge in the east and gives much rain.

Along Sumatra's North Coast in Atjeh, we can detect the influence of the subtropical drought belt. The northeast trade winds reach Atjeh only after they have passed over the mountains of Malaya during which they have been forced upward and have lost a large proportion of their moisture and so are dry. From a southerly direction only descending winds, which can give but moderate or little rainfall can reach the northern coast. Beyond Diamant Point however southeastern winds can bring rain. These and other conditions are to be seen in the data in Table 93, page 424.

Even though many of these stations

Table 92

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

IIIb. In long narrow valleys, basins and on plateaus.
Total above 2,000 m.

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Koeta Tjaneh......	370	25	197	182	116	205	255	265	146	101	141	213	336	306	271	2537	12	0
Sidikalang........	1066	18	214	245	173	275	282	183	116	111	119	215	290	311	243	2564	12	0
Balige............	912	35	158	180	162	192	192	135	102	77	120	161	236	231	229	2017	11	0
Siborongborong....	1320	23	138	186	164	228	206	139	90	78	112	201	233	235	209	2081	10	0
Taroetoeng........	1076	28	191	235	181	224	199	131	83	77	103	139	211	224	219	2026	10	0
Padang Sidempoean.	283	52	176	210	180	200	198	143	95	81	124	155	248	243	259	2136	10	0
Rao...............	298	17	155	211	172	191	223	164	89	63	111	155	214	206	198	1997	10	0
Loeboesikaping....	450	41	231	369	269	346	451	317	236	205	297	360	515	474	415	4255	12	0
Pajakoemboh.......	512	52	167	273	207	234	250	168	120	99	153	164	223	236	268	2395	11	0
Baso..............	909	17	154	218	136	196	227	165	103	92	145	180	189	235	186	2072	11	0
Fort de Kock......	927	52	193	228	168	214	246	179	130	92	149	169	229	223	242	2269	11	0
Fort v/d Capellen.	460	24	134	234	182	203	210	138	118	78	128	153	220	178	198	2040	11	0
Savahloento.......	260	37	141	257	169	225	273	164	125	93	113	145	213	217	226	2220	11	0
Solok.............	390	52	146	254	202	217	220	145	114	73	122	137	214	211	239	2148	11	0
Moearalaboeh......	430	20	119	263	173	242	255	180	107	88	114	139	235	230	203	2229	11	0
Tjoeroep..........	635	14	152	261	190	231	205	131	85	76	112	190	213	232	262	2188	10	0
Padangboernai.....	384	17	153	177	209	205	204	258	114	103	128	183	209	264	196	2150	12	0
Negeribatin.......	900	16	161	270	218	197	212	192	127	91	129	170	235	291	235	2367	11	0

Table 93

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

IV. The Northern Coast of Atjeh

Place	Elevation above the sea in m.	Number of years of observa-tions	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Peukan Ateuë......	8	10	123	171	128	143	133	123	52	55	64	144	142	170	230	1555	9	2
Oeleuëkareng......	3	10	117	146	94	139	97	117	59	43	71	138	152	151	232	1439	7	2
Koetaradja........	4	52	123	144	94	97	105	151	91	103	108	168	177	179	209	1626	9	0
Tjotpaja..........	1	9	79	164	66	110	55	60	40	38	61	129	152	218	204	1297	6	4
Koreëngraja.......	10	14	79	148	86	124	97	62	22	22	20	75	84	138	196	1074	4	3
Segli.............	at sea level	19	115	210	164	143	138	96	49	57	45	76	156	218	305	1657	7	3
Meureudoe.........	at sea level	12	96	171	181	166	107	110	56	49	49	88	158	205	292	1632	8	3
Bireuën...........	5	19	96	170	109	149	104	130	72	80	67	115	185	234	236	1650	9	0
Lho' Seumaweh.....	at sea level	36	101	191	65	70	87	113	80	85	92	106	167	202	283	1541	6	0
Pantonlaboe.......	3	10	110	228	82	64	90	122	81	82	91	98	149	183	253	1523	5	0
Idi...............	at sea level	28	127	237	76	49	67	101	115	100	137	135	190	294	495	1996	9	1
Perlak (Peureula).	7	14	139	261	98	77	67	109	83	93	130	151	162	210	280	1721	7	0

have been established but a few years, so that in the course of time it is possible that there will be considerable variation in these averages, the data here given indicate the general character of the rainfall, which will not change so much but that the following general points will remain valid: Low monthly averages, for the greater part not above 150 mm.; low annual totals, something more than 1.5 m.; and few rainy days. Toward the east and around Diamant Point, however, it is distinctly more rainy. Kroëng Raja, facing directly toward the north has therefore the least rain. Averaging the rainfall of these 12 stations, it is true June, July, and August with 67, 67 and 78 mm. have but little, yet still somewhat more rain than stations (Table 91) of the long narrow valleys, which show averages of 68, 55 and 74 mm.

Jumping now to the opposite, the southeastern end of Sumatra, we see in the eastern part of the Lampongs (Table 94, page 425) that some similar rather dry months occur, these are here caused by the dry southeastern monsoon. While this effect is of course most noticeable in the east of this region, yet the effect is also still clearly to be seen in the gap of the mountains at Telokbetong, in the so-called Way Lima tract.

However since the east monsoon does not reach Sumatra the year round, the average in the long run of the relatively dry months June to September remains still above 60 mm. Even so we can more properly speak of a distinct (relatively) dry season for this part of Sumatra, as contrasted with a (relatively) wet monsoon.

The one remaining part of Sumatra, consisting of the extensive lowland and low hilly land lying between the Barisan mountain range in the west and the Straits of Malacca and the Java sea in the east, extending all along that eastern coast of the island from Langsa to Lower Palembang has only one general type of climate (see Table 95, page 426). Almost everywhere, that is to say at the foot of the mountains, the annual average lies between 2 and 3 m. On somewhat higher land the annual rainfall lies between 2.5 and 3 m. while close to the sea more between 2 and 2.5 m. On the islands of the Riouw and Lingga Archipelagos the rainfall is also about 3 m. But in general the monsoon influence is weak; "dry" months under 60 mm. do not occur, while months which average less than 100 or above 400 mm. are infrequent. Table 95, page 426, includes only those rainfall stations with more than 20 years of observations.

Thus with practical certainty we may state that over this whole region, with

Table 94

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

V. Southeastern corner of Sumatra (Eastern part of the Lampongs)

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Wiralaga........	± 2	18	121	297	255	248	207	170	118	69	45	75	116	197	303	2100	9	1
Menggala........	18	27	137	426	311	314	237	152	113	95	93	119	149	246	353	2608	10	0
Soekadana.......	26	18	129	349	265	298	203	158	111	73	82	85	99	153	278	2174	8	0
Lab. maringgai..	2	18	107	267	237	208	232	194	177	115	96	70	113	122	217	2048	10	0
Kaliandah.......	35	37	130	286	226	200	200	176	133	84	78	86	112	244	242	2067	9	0
Redjosari.......	95	21	114	253	249	259	175	119	94	67	63	73	117	153	223	1845	8	0
Gedongtataän....	112	25	131	246	244	219	188	123	78	78	80	96	114	154	226	1846	8	0
Wailima.........	±140	26	131	247	224	214	142	105	76	69	67	67	101	127	205	1644	8	0
Kedongdong......	118	17	104	228	215	196	147	105	71	73	63	68	92	159	175	1592	7	0

an area of quite 7 times that of the Netherlands, the soil is practically always wet or is at least moist. The conditions here remind us very strongly of those of the other islands lying on the equator, although here and there are important soil differences which must be ascribed to other influences than those of the climate.

* * * * *

Except for the rainfall, for the present we can in general say but little about the climate of Sumatra, at least in so far as it concerns the soil. Because of the position of this island on the equator, as a rule the atmosphere is more moist than is that of Java or of the Smaller Soenda Islands. One evidence of this is the lower elevations at which the long beardlike moss grows in the high tropical forest. On Java the moss seldom comes lower than 1,000 m. while on Sumatra many times it may be found as low as 700 m.

The temperatures show no special characteristics. They are the same as everywhere else in the Archipelago and thus vary mainly according to the elevation above the sea. Only locally (as for example in Deli) can Föhn winds (Bohorok) widen the air temperature range from about 20° to 31°C to the limits of between 17° and 36°C.[6] In so far as I know, as to how the soil reacts to these conditions has never been gone into. However, since the dry periods are never longer than four extremely dry days in succession, the influence on the soil cannot extend to any considerable depth.

The only sporadic occurrence of "dry months" in any one time and place leads one to expect that the soil temperatures and the moisture should be very uniform. As yet no observations regarding those are to be found in the literature. On Sumatra, however, the density of the forest cover[7] is not so great as in the southern and eastern subdivisions of Borneo. While in this latter region 89% of the area is forested, for Sumatra that figure is 62%. For the separate regions the percentages forested are:

Atjeh and dependencies..................	79%
East coast of Sumatra....................	75%
Riouw Archipelago (Siak).................	74%
Djambi..................................	67%
Sumatra's West Coast.....................	67%
Lampongs................................	60%
Palembang...............................	44%
Benkoelen...............................	42%
Bangka and Billiton......................	36%

But when we compare these with Java's figure of 23% it is evident that through its influence upon the soil climate and in other ways the tropical high forest of Sumatra must still be of great

6. See: Braak, Klim. v. N. O. I., II, p. 41 ff.
7. See: Versl. D. Boschwezen in N. I. (1930), p. 174; and Tectona XXVI (1933), map opposite p. 422 (F. W. Endert).

Table 95

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON SUMATRA

VI. Central East Sumatra (from Langkat to Palembang)

Place	Elevation above the sea in m.	Number of years of observations	Rainy days per year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Humid (wet) months	Arid (dry) months
Close to the mountains																		
Bandar Baroe	864	29	173	635	543	553	614	480	370	255	370	505	673	622	707	6327	12	0
Lau Boentoe	125	28	161	290	169	246	264	331	248	213	291	372	484	390	377	3675	12	0
Bekalla	62	52	144	167	121	153	183	256	171	166	237	288	331	311	257	2640	12	0
Siantar	392	21	127	257	205	228	235	284	159	148	226	298	415	264	235	2963	12	0
Pasirpengarajan	50	21	177	317	252	330	286	220	149	120	162	243	312	336	346	3071	12	0
Bangko	75	26	177	319	285	349	321	237	153	151	164	219	274	318	377	3167	12	0
Soerolangoen	100	26	142	396	283	342	280	210	149	140	161	200	260	349	372	3142	12	0
Ma. Beliti	67	22	139	307	228	309	269	195	142	121	129	178	277	252	343	2750	12	0
Lahat	110	52	171	484	360	396	329	231	138	120	136	167	204	287	395	3247	12	0
Ma. Doewa	148	35	149	301	238	289	302	207	149	136	132	117	165	243	303	2582	12	0
Lowland along the sea																		
Langsa	5	23	138	267	90	101	132	228	181	153	185	226	294	242	312	2411	11	0
Kw. Simpang	16	51	139	194	89	90	131	170	138	117	192	231	263	266	297	2178	10	0
Medan	14	52	142	134	89	108	129	176	131	133	174	209	263	249	224	2019	11	0
Tdg. Balei (As.)	2	29	108	155	92	97	115	133	117	113	122	174	255	206	159	1737	10	0
Lab. Bilik	7	30	130	187	139	122	151	137	136	106	180	237	264	280	200	2138	12	0
Tanahpoetih	3	17	112	155	110	165	200	128	109	91	150	235	251	230	207	2035	11	0
Pakanbaroe	5	24	134	232	167	246	226	171	117	102	144	204	270	251	248	2379	12	0
Taloek	about 30	21	136	257	220	268	330	219	136	91	124	200	305	358	336	2844	11	0
Rengat	" 20	32	127	200	174	206	215	167	105	99	126	152	205	234	199	2082	11	0
Ma. Tebo	36	22	129	241	257	272	234	192	133	107	120	157	225	270	279	2488	12	0
Djambi	about 15	52	174	226	207	271	252	187	126	111	145	168	234	289	268	2493	12	0
Palembang	4	52	162	293	241	311	284	188	119	96	106	115	205	270	334	2561	11	0
On the islands																		
Bengkalis	2	52	145	175	128	203	248	188	126	120	167	243	275	332	284	2490	12	0
Tdg. Pinang	4	52	156	334	185	220	277	241	217	196	211	231	284	325	358	3079	12	0
Penoeba	5	43	124	272	146	160	195	236	211	202	220	212	233	243	301	2632	12	0

significance for the soil and soil processes.

* * * * *

As has been said in the introduction, from here on we shall not consider Sumatra further as a whole, but the island will be treated region by region. For this purpose the political subdivisions can for the most part be used, though they will not be followed in all cases. Here and there it is necessary to overstep the political or economic boundaries. To some readers this may seem somewhat arbitrary but I feel compelled to do this because of the purposes of this book.

* * * * *

I. THE MOUNTAINOUS REGION OF ATJEH

The general character of this mountainous region has been described by Zwierzycki[8] as follows: "waste and steep. The differences in elevation between the mountain tops and the soil of the valleys and depressions is very considerable and

8. J. Zwierzycki, Jb. Mijnw. N. O. I. (1919), Verh. I, p. 18.

these latter have mostly a V shape. Only seldom, and then in relatively easily weathered rocks, do these valleys become broader in which case they are also inhabited. Otherwise the mountains of Atjeh are covered by an unbroken tropical high forest."

Referring to the condition of the natural vegetation of Northern Sumatra, Luytjes[9] nevertheless says: "It is desirable to break with the conception that Sumatra for the greater part is covered with immeasurable tropical high forests. On the contrary, surrounded by mountains, many highlands are completely deforested." The one statement is just as true as the other. That this is so becomes evident if one travels through the land as Volz[10] has done.

Weathering Processes and the Resulting Soil Types

From the Pretertiary rocks, in so far as these consist of slates, as well as gravelly slates and quartzitic sandstones, there came into existence under the prevailing conditions of continuous lixivious weathering in the mountainous land of Atjeh only clayey, loamy and sandy soil types, which at times are very brightly colored. So long as the rocks are not of other kinds and not more than those just mentioned, all the soil types formed from them must be quite rich in quartz, especially in the form of fine sand and silt. The colloidal constituents can be little else than hydrogen clay.

But in these formations there are also many limestones. Where these can exert their influence on the weathering clay these clays naturally possess more lime in the absorbed form. On the limestone as a separate parent material much soil does not lie and only an "exceedingly scanty open field vegetation exists. Agriculturally these limestone soils are useless."[11]

Between the above-mentioned Pretertiary rocks however in a number of places there are also inclusions of old, basic volcanic material, such as diabase, and diabase tuff. Elsewhere andesite and andesite tuff occur, with some gabbro. In the localities where such rocks occur another sort of soil develops. It is richer in iron and in general better. But since the formation is old and compact, the weathering processes proceed relatively slowly, so that erosion has ample opportunity to carry away the newly-formed soil just as fast as it is formed. Consequently soils with considerable depth cannot occur (see Fig. 162, page 428).

Also the very numerous outcrops of granite only to a limited degree favorably modify the soil on the Atjeh mountains. Not only are the granites not rich originally, but they weather slowly, and unfortunately the erosion can keep up with this weathering so that the weathering contributes quartz to the soil of which there is already no lack. In so far as these granites are not still older than this sedimentary formation and thus stick up through it as exposed "windows," they are younger, in which case they have been forced up through the sedimentaries as magma, which has metamorphosed the rocks in their vicinity. This means that these altered materials show still more resistance against weathering. Therefore, occurrences of this last type of granite have neither a quantitative nor qualitative effect upon the thickness of the soil or upon its improvement.

The early Tertiary rocks which, according to the above-referred-to map of Zwierzycki, occur over a considerable area in the mountains of Atjeh, consist to an important extent of quartz-rich conglomerates, coarse and fine quartz sandstones, etc., which, taken by and large, certainly possess still more quartz than the Pretertiary rocks. That some of these sandstones also contain some tuffaceous material, doesn't make much difference in this connection. When all these rocks weather, there must be left over much quartz gravel, and coarse and fine quartz sand, as well as fine quartz dust. A characteristic peculiarity of these Old Tertiary rocks seems to be a content of mica flakes, presumably coming from the older granites. Of course

9. A. Luytjes, Tectona XVIII (1924), p. 328-348; especially p. 347.
10. W. Volz, Nord-Sumatra II. Die Gajoländer (Berlin, 1912).
11. Volz, l. c., p. 353.

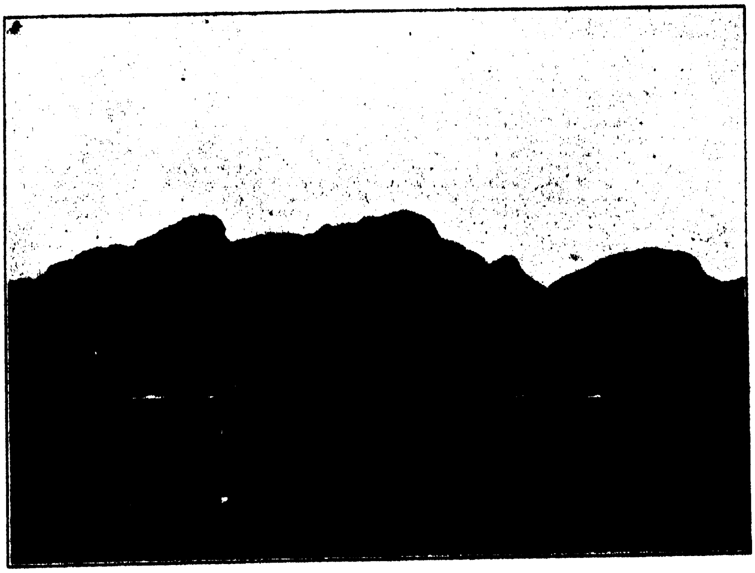

Photo by A. Luytjes

Fig. 162. Suratte Passage, Great Atjeh. Permocarboniferous slates and limestones. Where weathering soil can exist, there forest stands. Not of any use for cultivated crops.

this mica comes directly into the soils of this formation. Flowing water again further sorts out the whole of the weathering residues and farther on, beyond infertile quartz gravel and quartz sand banks, a very moderately fertile loam is deposited which is rich in quartz powder. Also a relatively small amount of clay is left which, however, contains much extremely fine quartz dust (an excellent pottery clay).

As indicated by the repeatedly intercalated layers of coal, it is likely that the coarser facies of this formation were land deposits. But the finer facies are without doubt marine, so that this clay could have been itself absorptively saturated in sea water previous to having settled down onto the sea bottom for a long time. According to Zwierzycki[12] "during (subaqueous) weathering the shales of this formation take on a gray color while (in the case of subaerial weathering) they develop brown, yellow, and reddish purple colors, and fall apart in shell-like blocks." Thereafter these blocks then again further disintegrate and the fine detritus is all too easily carried along by flowing water. Now if there is not too much water taking part in the breaking up and disintegrating process, still quite a bit of plant food remains available for the vegetation. For the above reasons deep soils will not be found on these rocks in the Atjeh mountains. Only the bits of colluvial and alluvial flats must be of deeper soils.--Although young Tertiary rocks do not occur in the real mountains of Atjeh, this formation borders the region along the north and east coasts into Langkat. On the west coast there are also a couple of spots, namely, a basin behind Meulaboh and a fringe along the north coast, behind Singkel. However, since at most they form but hilly land they will be included in the discussion of the low land of the coastal strips of Atjeh.

On the other hand a number of tracts of relatively young volcanic activity merit separate mention here:

a. Poeloeh Weh, with Sabang.[13] Parent rock: hornblende andesite,

12. L. c., p. 33.
13. J. Zwierzycki, Jb. Mijnw. (1916), Verh. II.

presumably[14] of intermediate composition, for quartz occurs sporadically in it.

The brownish red lixivium, residual upon the andesite itself, as well as upon the accompanying tuffs and "agglomerates," which are of approximately the same primary composition, is not very deep in color and relatively heavy and sticky. In other respects it has the usual characteristics of this soil material.

b. The region about Sumatra's most northerly point, Kaap Pedro, and extending toward the east-southeast, to and including the Goudberg and Weesberg. The parent rocks[15] are: Hornblende-augite-andesite, with a considerable proportion of tuffs, also pumice stone tuffs.[16] Since the rainfall is relatively light in this part of Atjeh and the tuffs are very pervious, it is strikingly dry, as a result of which the weathering proceeds only slowly. The vegetation is therefore far from being a closed high tropical forest. Instead there is much miserable grass vegetation, which is again and again burned off. In consequence only on exposed moist slopes has the soil reached the stages of virile to senile lixivium, while many times it is still a very juvenile, sandy tuff material. This last is finally transported and deposited in adequately moist plains. Then it is naturally a source of fertility. This is the case in the west, in the plain of Great Atjeh, as it is in the east in the plain of Pidië.

c. According to data from Hirschi[17] Mt. Peuët Sagoë, a volcano south of Samalanga consists of andesite, more on the basic side. The same apparently applies just as well to:

d. A number of smaller outcrops of igneous rocks, in the hilly land just south from the north coast, lying in a line east and west, approximately between Panteh Radja and Bireuën. Taken as a whole these rocks give the impression of being the result of an eruption along a fissure.

e. Much larger and more important is the young volcanic region, directly south from Bireuën where the Gajoe road runs through it to Laoet Tawar. In there lies the bigger and higher, but already somewhat older volcano Boer ni Geureudong and its younger, still more active partner Boer ni Telong. Since for such a long time (speaking in the sense of soil science) the former volcano has not been active, its slopes have weathered much farther than those of the latter one. On the higher, cooler portions of the older Geureudong at 1,000 m. elevation and more, under a tropical high forest we find a deep orange-red, relatively heavy lixivium soil, in the third quite senile stage of weathering. At 1,000 m. the humous surface soil is still quite thin, while higher up it becomes thicker. Lower down, more toward the foot of the mountain long foot slopes run out. On these over great expanses the tropical high forest has given way to a vegetation of grasses and ferns which are repeatedly burned off, after which they at once grow up afresh. Under this vegetation, which characterizes not alone the "blangs" (cogonals)[18] of Atjeh but unfortunately occupies great areas in most all parts of Sumatra, the surface soil is a black loose horizon from 15 to 45 cm. thick though sometimes also much thinner. Below this is a bright reddish brown or orange-yellow lixivium, appearing to the eye just about the same as that which is found somewhat higher up, under the tropical high forest. One must dig some meters below the surface before more juvenile horizons are found. Yet everywhere we have to do with older, mighty lahars, all of which in the first place passed through the form of the cogonals ("blangs") (see Fig. 163, page 430). In the second place the construction of the great "Gajoe Highway" has exposed a number of of profiles (see Fig. 164, page 431), which clearly demonstrate their lahar-character. In the much weathered surface layers even yet a number of large stones are to be seen. These corroborate the belief that in former times these layers also were lahars.

From the Boer ni Tèlong, particularly in its southern sector, important lahars have likewise come down. However, there have also been a number of lava

14. Analyses still not available.

15. Analyses still not available.

16. Volz, l. c., pp. 223, 234.

17. H. Hirschi, T. Kon. Aardr. Gen. XXVII, p. 741-763, especially p. 760.

18. Open grass lands, with *Imperata* spp. predominating. Cf. p. 372.

Photo by J. C. v. d. Meer Mohr

Fig. 163. Bare (deforested?) Boer ni Rakal, near the Gajoe Road, North Atjeh. Perhaps a secondary point of eruption, with a lahar in front. "Blang" vegetation, cogon (Imperata spp.) and ferns in the foreground.

streams. And judging from various profiles along the Gajoe Highway it appears that this volcano has also had ash eruptions, even not so long ago (see Fig. 164, page 431). At about Km. 69 on this road, as we pass from the older Geureudong landscape into that of the Tèlong, the soil also changes. The orange red color makes way for the light gray of a juvenile soil material, on which lies a humous surface soil darker in color, but still of quite another tint than the black color of the surface soil on the lower lying blangs (see Fig. 165, page 432). The quality and fertility are also entirely different. We will later return to this point.

Apparently the rock of this volcano is not especially basic, rather intermediate, on the acid side. Presumably the iron content is not high, for the subaerial lixivium is not a deep reddish brown, but much paler. Moreover the lightly weathered ash soils are not colored intensely brown.[19] Near to Lampahan this Gajoe highway runs over a lava stream of a pale beige color and rich in glass. Since as a whole, no earth lies upon this lava one is amazed how the characteristic tree of the Gajoe landscape, Pinus Merkusii, with its roots in the little holes and cracks of this flow is able to shoot up and attain such a respectable height. The rock is thus certainly not infertile and appears to weather sufficiently fast for the vegetation.

In other road cuts we see just below the surface a preponderance of large lahar stones. In still other places the profile many meters deep consists of fine ash, still unweathered (see Fig. 165, page 432), and without a single large stone.

From all this it appears that the Boer ni Tèlong has behaved as an ordinary Netherlands Indies volcano, as has the Geureudong, only at a somewhat later date. Therefore while on the surface the Geureudong soils are already relatively senile, the Tèlong soils are more juvenile, and are thus more fertile.

According to the map of Zwierzycki this young volcanic region extends on out still further toward the south, so that not only do the Boer ni Poepandji, Boer ni

19. As long as analyses are still lacking, we must carry on with provisional criteria of such a sort as this.

Photo by Mevr. Swart-Stadlmair

Fig. 164. Atjeh. The road to Gajoe, at km. 66, shortly after construction. The cut shows excellently the alternation of stony lahars and fine ash, whether the material had been deposited as a lahar, or as an aeolian deposit.

Salahnama and the Boer ni Paja belong to it, but also the Boer ni Bias. Presumably these four are all smaller and somewhat older points of eruption (see Fig. 166, page 433). Towards the north a mass of lahar material from the Geureudong appears to have flowed out in the direction of Lho Seumaweh. This material has formed the extensive field in the landscapes of Nisam and Tjoenda. However, this happened so long ago that in general the soil on the old lahar has now become quite senile and is of only moderate fertility.

f. More southerly, in the extension of the line Boer ni Geureudong, Boer ni Tèlong, and Boer ni Poepandji, there is another Mt. Geureudong, which is supposed to be a volcano. Such suppositions have also been mentioned with respect to Mt. Loser. For the time being, however, we know too little to warrant our now discussing this matter further. Likewise, because of lack of definite information we ought not to devote any greater attention to other occurrences of younger effusives, lying in practically uninhabited regions. Regarding the soil of these regions there is not much which we can add to a single sentence by Taverne:[20] "Characteristic of the andesite (in the Tertiary basins of the Woi ni Lesten) is the typical reddish brown, chocolate colored soil weathered from this rock, through which it becomes possible to immediately recognize the terrain as such."

Putting one thing and another together, we come to the conclusion that in the mountains of Atjeh, on the mountain

20. N. J. M. Taverne, Bijdr. geol. Gajolesten enz., Jb. Mijnw. N. O. I. (1921), Verh. I, p. 162-268; especially p. 178.

Photo by Mevr. Swart-Stadlmair

Fig. 165. Atjeh. Along the road to Gajo, at km. 81. The fresh road cut shows fine ash some meters deep. On it is tropical high forest, with a distinct layer of humous surface soil about 1/2 m. thick.

slopes which for the greater part are steep and on which it continuously rains a good deal, the surface erosion must be very intense, so that but little soil can remain. All soil formed as surface forest soil washes downwards and comes directly into the less steeply sloping flatter stretches, where the deposits build up fertile plains. This happens especially in the basin-shaped and longer narrow valleys between the mountain ranges, where the rainfall (see page 423) is considerably less than on the higher slopes. Thus the intensity of soil leaching is also less. Since these colluvia and alluvia are always more or less sandy and thus pervious to air, the color is usually a light brown to biege, and the soil is almost always in a condition to be easily worked. It is conceivable that some river or small stream deposits are formed from such a high proportion of coarse and fine quartz that soils derived from such deposits may be extremely infertile. As yet, however, such extremes have not impressed any observer,--at least as far as I have been able to find in the records no one has recorded any such impression. Actually the materials which have been transported by the rivers must have been derived from all kinds of rocks and well mixed together so that practically all the deposits have a moderate fertility. Hence there are no extremes in either direction.

If now we turn to the discussion of the

Evaluation and Utilization of the Soils

of Atjeh's mountainous land, then it appears that this as a whole fits in with the above recapitulation. Isn't it always true that infertile mountain slopes stand in contrast to fertile valleys? and that so long as there is still land available in the valleys, no one would be so foolish as to go into the mountains and endeavor to exploit the slopes? Indeed in the mountainous

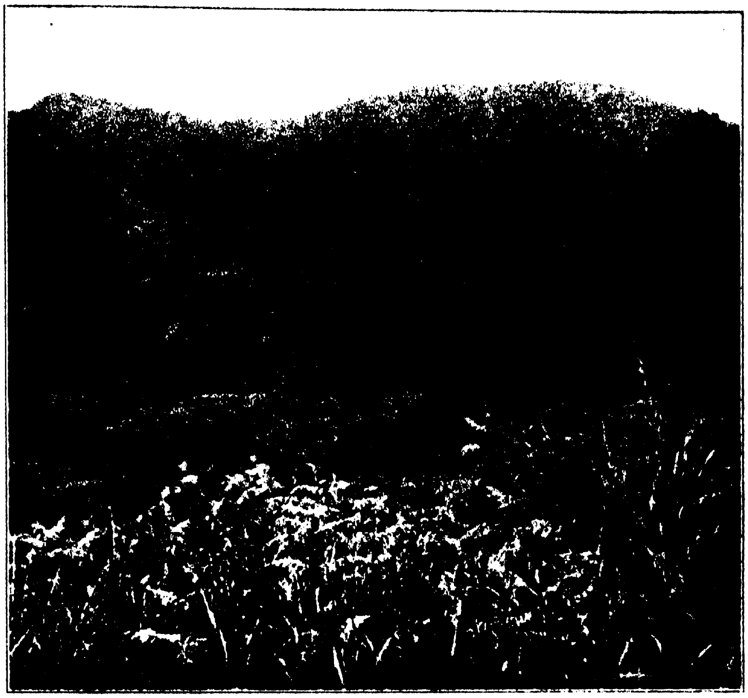

Photo by Mevr. Swart-Stadlmair

Fig. 166. Old kaiñgin at the foot of the heavily forested Boer ni Poepandji, near Takengon. Elevation more than 1,200 m. In the foreground are cogon (Imperata spp.) and ferns.

interior of Atjeh all deposits of material washed from the slopes lie in the valleys. In addition, there is sufficient rainfall so that the rivers in the mountains flow throughout the year. Moreover the greater part of the mountains are still well forested, which is very advantageous for a satisfactory regulation of the water in the rivers. The consequence is that paddies are in the valleys while no kaiñgins are on the slopes (see Fig. 167, page 434). Regarding this, Kreemer wrote:[21] "In Gajo and Alas and in many parts of Atjeh where there is an abundance of flat land available for the cultivation of the principal crop, upland rice kaiñgins are absolutely unknown. Only where paddy lands are lacking, such as in many localities along the east and west coast, one may expect to find upland rice cultivation." The coastal regions will be discussed later.

In the valleys thus lie the paddies. The greater part of these are well irrigated so that they are independent of the vagaries of the rainfall. The yields of about 15 quintals per hectare are quite regular, but not high. Considering the parent rocks and at the same time the elevation, this is a satisfactory yield. There is no doubt, however, that if irrigation were always adequate, even with the generally rather poor water, higher yields could be attained especially if N and P fertilizers were also used.

But the native will not rapidly commence to grow kaiñgin rice, for except on the youngest soils on the volcanic terrain, such as those on and around the Boer ni Tèlong, the soil on the slopes is too poor and too scant. On the cogonals (blangs) of the Boer ni Geureudong, however, the soil is no longer kaiñgined, much less the cogonals on sandstones and other quartz-rich rocks.

21. J. Kreemer, Atjèh, Dl. I, p. 446.

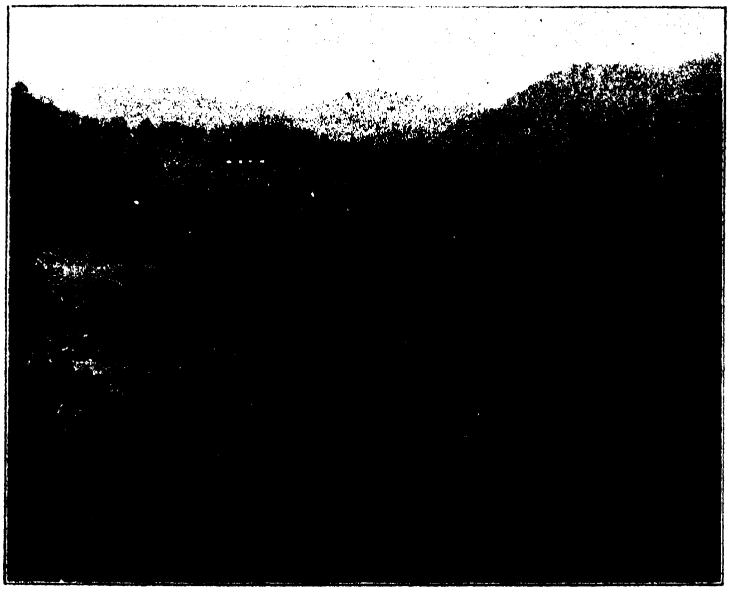

Photo by H. M. Neeb

Fig. 167. The Gajo Lands. Lempelan Pinang village, on the Woih ni Padang. Typical Atjehan landscape: flat occupied by paddies, cocos marking the villages at the foot of deforested slopes, with groups of pines, especially in the ravines. Mountains in the distance covered with heavy forest.

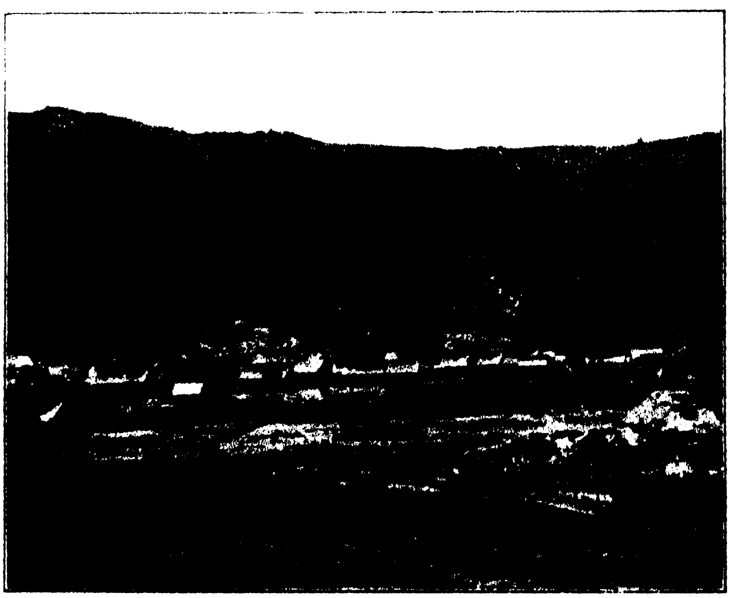

Photo by J. M. Baron v. Tuyll v. Serooskerken

Fig. 168. Peusangan village with paddies on the forelands along the Peusangan river, Northern Atjeh. Beyond are unutilized, bare hills with scattering Pinus.

If anyone who does not know that country examines the deep black soil under the cogon (Imperata spp:), the elephant grass and ferns, he is at once astonished and gets the impression that the soil is an excellent one, most suitable for cultivation. However a cultivation experiment[22] has already shown that this black soil is anything but rich. On the contrary it is poor and of an entirely different character from the dark brown, humous surface soil in the old tropical high forest, especially that lying higher up on the flanks of the volcanoes. The black blang soil is as a rule thicker. That is to say, if tropical high forest stands at the same elevation as the blangs, then in the forest the humous surface soil is, at most, only a few cms. thick, while the black surface soil of the blangs may be as deep as from 10 to 40 cm.

It is possible that the remains of the burned grass and fern vegetation color the soil so intensely black. However, it is not certain that burning is the only reason for the black color. Previous to considering such soil on Sumatra and those on Java (about which more later) when describing Flores and likewise Celebes, repeatedly I had intended to remark that, also without burning, such a black layer 0E can form under cogon (Imperata spp.) and more especially under fern vegetation. If then, the first layer below, E, lying under this black is also a senile and poor lixivium, as it is here on the northern foot of the Geureudong, then the surface black layer 0E is also senile. If on the contrary the underlying ground E is still juvenile, as is many times the case on the Batak plateau, then also the surface soil 0E is much better, both in the nature of the "humus" and in the content of plant nutrient materials. The deceptive dark coloring is thus anything but an infallible indication of beautiful, rich humus.

Regarding the above-mentioned "blangs," those expanses of cogon grass (cogonals, Imperata spp.) the opinion quite generally prevails that they have come into existence as the result of former kaiñgins of the natives. But if the people now in those localities practically never kaiñgin, as seems to be the case in the Atjeh mountains, this opinion can hardly be correct. In other parts of the Archipelago, such as Java, Flores, and Minahasa, we also find vast cogonals but there, so to say, the surrounding forest is now being attacked by the kaiñgin agriculture, and the progress of the phenomenon can be seen clearly. The forest is driven back, and the cogonals gradually enlarge. Even the cogonals, after a number of years, are kaiñgined over again. But here in the mountains of Atjeh, on the blangs and around them in the forest there is no kaiñgining to be seen; the natives plant lowland rice in the paddies in the valleys. Apparently the blang soils are too poor and unsuited to kaiñgin agriculture and yield too little. The same seems to be true of the forests near them. But with or without being set afire by the natives, from time to time the blangs do burn over. So we can imagine that near to the settlements of the natives in the valleys, at the foot of the slopes along the transition to the plain, somewhat higher lying lands had been tested for use as paddies but again abandoned. On these latter fields the first grass plains originated, and are still used as pastures. They now and then burn off by themselves, or are intentionally set on fire. Such fires also burn a part of the edge of the forest. In moist, fertile ravines the forest would rapidly regenerate, though it would not on ridges with poor soil (see Fig. 168, page 434). In this way the cogonals gradually extended back into the uncleared forest land, which in the course of ages becomes converted into blangs. And it is even plausible that in Atjeh, as also elsewhere, for example on Borneo, there are many blangs (cogonals) in whose origin the natives never have had a hand. To contend that all cogonals which now exist are the result of kaiñginging seems to me a little too narrow a conception. Take for example some blangs upon young lahars, where now sporadically pines shoot up spontaneously. I am even inclined to suppose that taken as a whole no tropical high forest had existed on this land and thus there is no question of driving back or replacement of the forest by the blang

22. See: Kreemer, l. c., I, p. 438.

or cogonal vegetation. However, only painstaking investigations on the spot, particularly by foresters or agriculturists cooperating with soil scientists, will give definite information about this.

* * * * *

The cultivated crops of the natives are to be found in the valley plains. Greatly predominating over everything else is lowland rice. It is true that the yield of paddy per hectare is not extraordinarily high, but still it is sufficient to enable the Gajoes to sometimes produce more than they themselves can consume, so that a surplus is at times available for export. In the lowland and on the coastal plain (see below pages 442-443) surpluses are of more significance. We are now considering the mountain lands, which are higher and cooler. And of course the harvest is largely determined by the soil. So it is at once clear that in the environs of the Boer ni Telong, and especially southward a scarcity of rice never occurs. On the contrary a significant surplus is obtained, sufficient to provide the European plantations located in this region with rice and then sometimes even some extra can be exported to other places.[23]

That the soil in this locality excels that of other portions of the mountainous land of Atjeh appears also from the fact that potatoes are raised with success (this is at an elevation of 1,100 to 1,200 m.!) in spite of the diseases which affect this crop. In how far the nature of the soil is responsible for this, as in certain cases is indicated elsewhere, still remains to be seen. In every case the use of fertilizers seems to be necessary.[24]

Following the example of the neighboring European plantations the natives are planting arabica coffee with good results. It will appear in the long run whether the climate is favorable for this crop; the soil is apparently quite suitable.

On flat terrain, but also on the slopes of not too steep little ravines, where flowing water can always be obtained, vegetables, such as cabbage, are grown especially for export; not much is used locally. In short--it is clear that the locality lies under the influence of a young volcano, which has given the soil a high degree of fertility.

In the plantings of the coffee and tea estates west and east of the Boer ni Tèlong this also comes out very clearly. Especially in the east these estates which lie on tropical high forest land, the soil of which has a deep brown, humous surface layer of from 20 to 50 cm., under which there is pervious volcanic gravel and ash, certainly belong to the most fertile of the whole region (Fig. 23, page 149). A little cementing of the ash at a depth of about 1 meter, of such a sort that chunks dug out are easily broken up in the hand, does not detract much from the fertility.

Nowhere else in the mountains of Atjeh do we find plantation crops; in general the soil is quite too poor for them. Yet it ought not to remain unnoted that Taverne[25] stated that between the Gajo Lesten and the Alas country he found a large area of basic "andesites and basalts, younger than the Paleogene." This formation he indicated on his geological map of this region. We know but very little about the region referred to. It is therefore quite possible that the soil is suited for some plantation crops. "Younger than Paleogenic," however, does not say enough. If the eruptives are Tertiary, then that does not give much hope as they would have steep slopes, and a shallow senile soil. If however they are Quaternary, or even Recent, then more should be expected of them. There is also the objection that the locality lying in the almost inaccessible interior, is isolated too far from the outside world. Moreover in so far as is known, the terrain is very rugged, much cut up, and very thinly inhabited. Such conditions are not very much of an inducement to make a closer

23. Cf.: Mem. v. Overg. Orderafd. Takengeum v/d fg. Contr. Milius. (Dec., 1933), p. 6.
24. See: R. Broersma, Alg. Lb. Wbl. Ned.-Indië, 22 Juni 1923, p. 2531-33.--There at 1,200 m. elevation, the very humous soil is friable garden earth, but Broersma quotes the pioneer authority Veenhuizen as saying that manure is indispensable.
25. N. J. M. Taverne, Jb. Mijnw. N. O. I. (1921), Verh. I, p. 162-186.

investigation, and cannot stimulate the lust for plantations.

In the rest of the valleys, such as those of Geumpang, Tangse, etc. and in the large Alas valley, good paddies are found everywhere. Since these are properly worked they produce adequate crops of paddy, though for the time being there is no significant surplus of rice. Perhaps later the farmers will fertilize more, thus increasing the yield and so make possible the export of an important amount. A favorable factor is that here the water supply never causes any concern. In rotation with rice, but more especially in the house yards, the inhabitants plant vegetables and fruit trees. In passing it is worthy of note that in the history of agriculture of these regions so little mention is made of maize. On dry fields around the sides of the valleys, as well as in the houseyards tobacco is raised for home use. If after a couple of harvests tobacco doesn't do well any longer, a little sugar cane is planted for chewing and also for making a little sugar. In the Alas valley, as well as in Takengeun, some fruit is also grown.

Meanwhile the natives from time to time go into the forest to gather wood and other forest products, such as rattan and dragon's blood.[26] At times we read such statements as this: "the forests of Atjeh contain many kinds of good, hard wood."[27]--Such is to be expected of forests on these poor mountain slopes.

The tree of Atjeh most worthy of note is certainly Pinus Merkusii which seldom occurs in the closed tropical high forest. But it frequently occurs on the edges of it, on the cogonals, and on bare slopes (see Fig. 168, page 434). As a rule the presence of this tree is not a sign of high fertility. But the same is true of the conifers in Europe and North America. However these trees give a valuable resin, from which turpentine and rosin are obtained. For this reason they are not only conserved, but also are planted out to an important extent over the blangs (see Fig. 169, page 439). Since man there has an interest in them he can of course prevent the usual suppression of the pines by other forest trees.[28]

2. ATJEH'S COASTAL PLAINS AND LOW HILLY LAND

Behind the strip of coast, which in some places is broad, in others narrow, we come into a somewhat higher terrain. Along the northern and eastern coast the geological map of Zwierzycki shows this to be a completely continuous band while along the southwestern coast slightly higher land is shown as a series of somewhat larger to very small spots of "Quaternary" (terraces). Behind this is the much wider and more important Neogene. Although locally this formation rises to an elevation of several hundred meters, it is because this Neogene has been and still is of so much significance that it was not discussed in the same chapter with the mountains of Atjeh, but is considered here separately. For that matter, various Quaternary terraces have also been raised up to elevations varying from 80 to 120 meters.[29]

The coastal plain is to be thought of as made up only in part of river deposits. A large part of this region has been raised up out of the sea, just as even longer ago the hilly hinterland had been. But with the exception of the very youngest sediments, that happened so long ago that the soil has now for the most part lost the character of marine deposits.

Weathering Processes and the Resulting Soil Types

Whether the land be low and flat or whether it be somewhat higher and rounding or hilly, if it but lies in such a location that it can no longer be covered over to any significant degree by fresh soil material nor can have more sediment deposited

26. Dragon's blood, a red resin from Daemonorhops spp. and Dracaena spp., comes especially from Tangse.--See: P. Scholten, Mem. Onderafd. Lam Meulo (Dec., 1933), p. 65.
27. See for example: K. Th. Beets, Mem. v. Overg. Afd. Gajoe en Alaslanden (Mei, 1933).
28. Compare the interesting paper by A. Luytjes, De Pinus Merkusii in N. Sumatra, Tectona XVII (1924), p 323-349.
29. See: Jb. Mijnw. N. O. I. (1917), Verh. I, p. 211.

upon it, the influence and effects of one or another autochthonous weathering complex may be observed. Hence, whatever lies exposed there is to be thought of as a parent material for soil formation. This applies equally to the solid Neogene rocks of the foothills and to the allochthonous deposits of the lowlands.

Regarding the more or less solid parent rocks which comprise the Neogene, already in the introduction (see page 420) various things have been said. Now let us add the following to round out that statement: The materials from which these rocks have been formed were most probably originally deposited as sediments in the quite deep sea. Then, through continuous rising of the land with reference to the sea they were accumulating in a continually shallower sea and finally as land deposits. In the deeper layers we thus find much $CaCO_3$ (especially from Foraminifera) and upwards less and less with finally no lime at all, instead little layers of lignite which are so thin as to be unimportant. In the second place in the successive layers, from below upwards, we find an increasing tuff content, though that is the case only where volcanoes were in the locality. Where these were lacking, as for example between Idi and Langsa, the ash content is also lacking. The tuff reaches a maximum for example to the north of the Geureudong-Telong complex, as well as around the Goudberg, where some of the youngest Neogene rocks are almost pure volcanic tuffs. Of course between these two extremes there lie all sorts of transitional forms.

The climate along the north coast (see Table 93) is now such that although in the west it is significantly drier than in the east, yet nearly everywhere a leaching type of weathering exists, although it may well be that in the west this process proceeds more slowly than in the east. This, combined with the above remarks about the parent rocks, brings us to the following descriptions of the soil and ecological conditions upon the Neogene (and still somewhat younger) hills:

a. From Kwala Simpang to Idi.--Parent rocks: quartz-rich, free from tuff, poor in iron. Climate: almost without dry months. Soil: more or less sandy, lighter loam to heavy loam, of a yellow color, here and there pale red, at other times bleached to a grayish white clay. This last occurs in places where a high clay content and a small amount of water movement in the soil have brought about amphibian, and even subaquatic conditions. As a rule the humus content of the surface soil is low.

Vegetation: apparently originally practically everywhere tropical high forest, but not luxurious. When this is once destroyed, then it regenerates itself but slowly, or as a whole not at all, the land remaining covered by congonals.

b. Between Lho Seumaweh and Bireuën.--Parent rocks: predominatly tuff sandstones and tuff loamstones (in proportion as they originated out of coarser or finer ash, etc.). Climate: three months of average rainfall between 80 and 100 mm. and all the rest "wet" and above 100 mm. but the total annual precipitation still not as much as two meters. Soil: not seriously eroded, thus quite deep and in consequence senile, a light red lixivium, rapidly showing a lack of enough water for the vegetation. Naturally the greater part is forested, with little humus in the surface soil. The relative poverty of this pervious soil is not made good by an excess of water, which ordinarily should be able to compensate for the small content of plant nutrient substances in the soil.

c. Along the northern slopes of the Goudberg complex.--Parent rocks: likewise predominantly rich in tuff varying to purely volcanic. Climate: still less rain than in the locality (b) just described (see Table 93). Here, as also on the southern slopes, there are periods without rain as long and almost as severe as in the valley of Great Atjeh. Where the rock upon weathering leaves behind pervious soil material, subject to intermittent, slow washing out, there must develop from it a chemically not infertile but rapidly drying out, brownish red lixivium soil. Besides this however, here or there in this most northerly part of Atjeh, on lower convex terrains not higher than 100 m. where a difficultly pervious soil material lies, an alternating water movement in the soil ought to bring about the formation of a grayish black, clay-rich, strongly cracking soil. Personally I have not seen such a soil, but then I have travelled only along the highway between Segli and Kotaradja.

Nor in the publications concerning

Photo by L. Ph. de Bussy

Fig. 169. Atjeh. Natural group of pines (Pinus merkusii) near Lampahan on the higher open grass lands. In the left distance the Boer ni Geureudong, in the right distance the Boer ni Tèlong.

Photo by J. Kreemer

Fig. 170. Great Atjeh. Landscape in the Neogene hilly land on the northern side with Goudberg and Weesberg. Climate quite dry. Strong sheet erosion. Because of the repeated encroachment by man little opportunity for the formation of deep soils.

Atjeh have I found anything about such a soil, but that does not mean much,--as by now the reader already knows well--. Who is there who in describing a region in the Netherland Indies, observes the soil and writes anything about it?--It would indeed be interesting to have data published about the soil, such as of the localities around Kroeëng Raja or Lam Teuba, L. Baro or L. Nga, all lying about Sumatra's most northern point.

Around the Goulberg the forest does not amount to much, cogon covering all the knolls and slopes of the Neogene. Here and there stand some shrubs, in the ravines a few trees and some somewhat taller growth (see Fig. 170, page 439). Also the map by Luytjes[30] shows this region clearly as one vast cogonal.

* * * * *

Turning now to the low land and the coastal plains, we come to the most thickly populated portions of Atjeh, the soils of which are the most important economically. Of course the original material of the soils of these plains differs according to the source of the material deposited as colluvium and alluvium. This varies according to what the higher back country is. But besides this, however, notice must be taken of the differences between river deposits in fresh water and marine deposits in salt water. Along a slowly rising coast there is in addition also the combination of the former with the latter.

While with land deposits it is as a rule not difficult to indicate which river brought the sediment down--unless in a great low plain different rivers flow out close to each other, such as the Maas and Waal in the Netherlands--with marine deposits it is as a rule less easy, since the currents of the sea sometimes cause considerable horizontal displacements parallel with the coast. Thus the picture, usually simple in broad lines, can be greatly confused, and at the same time all kinds of differences may more or less balance each other.

On the topographic map of 1:40,000 it is very easy to distinguish the river deposits from the marine deposits. The former are recognizable by the natural diking of the rivers formed by more sandy deposits. On these are built the villages which thus in form follow the course of the river. If the river leaves this channel, then it makes a new channel with new dikes, and on them spring up new villages. The villages shown on the map thus indicate the location of both the present day and the former river channels.

The sea meanwhile throws up sand and mud banks (in various places, but not everywhere along the coast!). For the greater part these are parallel with the coast. Little by little these ridges come above the water and the slight depressions lying in between become gradually filled with silt and their beds being raised, are cut off from the sea, so that the water in them becomes less and less salty. These depressions are thus first swamps, then paddies. While on the somewhat higher sandy ridges the villages are built which in form follow the coast and dune ridges.

In this way was formed the northern part of the plain of Great Atjeh which is traversed by a number of dry ridges parallel with the coast, indicating that this portion of the plain is a marine formation. The rest of this plain shows only present day and earlier river channels, showing that it is the result of river action.--In a number of places on the north coast the same relationships are very clearly demonstrated. The most beautiful is to the north and northwest of Lho Soekon, in the region of the lower course of the Kr. Keureutöë and the Kr. Pasè rivers. Along the Kr. Blang Mè and the Kr. Djamboe Ajè rivers we see the predominating influence of these rivers, which have extended their deltas outward into the sea (as at Oedjong Peusangan and Diamantpunt). Southeast of Diamantpunt to as far as Langkat the river influence continues to predominate.

Meanwhile, some general qualitative differences may be observed. For example, between Langsa and Idi we would not expect it to be possible that the rivers would carry out juvenile sand and silt from a young volcanic origin. In fact, all alluvia and colluvia of terrigenous nature

30. A. Luytjes, l. c., Tectona XVII (1924), p. 323.

deposited have been senile and poor. On the northern coast, on the contrary, the Kr. Sawang, the Kr. Peusangan and the Kr. Meureudoe rivers without any doubt bring juvenile material down from the volcanoes which lie in the interior. Naturally this material has had an effect upon the plain. The valley of Great Atjeh is built up of mixed senile and juvenile material.

In this respect this valley of Great Atjeh is indeed a particularly favorable object of study. To the northeast lies the volcanic terrain of the Goudberg, etc., to the southeast Neogene, but the Great Atjeh river comes from still much further southeast where there are slates, sandstones, shales and even granite. To the southwest lie limestones, gabbro, and serpentine. In passing we may add that it is a great pity that there are no detailed data relating to the soils of this important plain. In all publications the soils seem to be considered as uniform throughout, for no one has recorded differences between the north and the south, nor between the Selimeum-Indrapoeri portion and the coastal strip. From what we do know we can now say that the soils are probably as follows:

a. Along the Great Atjeh river lie lighter sandy soils with much quartz sand.
b. In the southwest, close by the mountains perhaps there are soils still rich in lime. However, the farther one comes out into the plain, the poorer the soils will be in this element. But on the coast they contain more lime. Above all, there is much quartz everywhere, either as sand or silt.
c. In the northeast, close by the volcanic outliers of the Goudberg, near Sumatra's north point, the soil is poorer in quartz, richer in clay, and heavier. The color of the lower portions is perhaps more gray to blackish gray, while the higher regions are somewhat redder. Upon approaching Kotaradja, however, because of the large proportion of quartz powder, the colors gradually change to a more pale reddish, light gray.

However, without accurate field study such deductions have little value, except as a goad to observation and criticism.

The above-mentioned pale gray color with a reddish cast, we see everywhere along the northern coast--in the large Pidië plain, at Meureudoe, Samalangan, Bireuën and still farther east. It is evident that the farther one goes out into the lowest land, against the coastal swamp zone, the less of this red or brownish color there is; here the gray to dark gray of the subaqueous soil predominates. The converse is also true: the nearer one approaches the hills, the redder and brighter becomes the tint of the soil which was perhaps once gray as deposited by the flowing water, but now lies exposed and weathers further subaerially. It is true the content of fine quartz sand makes the red color paler, but still it is there.

Because of the great number of small rivers which come from the mountains but little lowland of any extent has been cut off from the sea and transformed into fresh water swamp. The Paja Tjitjem, east from Lho Soekon, along the north coast is still the most important terrain of this nature, although this is already being nibbled at from all sides and more and more of the area has been altered into paddies. According to the description by Van Heurn[31] this "paja" is not a true swamp, in that over a large area it is only a couple of feet deep and, except for perhaps a couple of little spots of no significance, it is a mineral soil without the formation of peat. Also in Java pajas or rawahs exist without the formation of peat, and with a solid soil. The pH of the water standing in such a swamp must be higher than 4.5 to 6. Of the Paja Tjitjem we do not know the pH but it would be easy to find out. According to Van Heurn, the soil is a gray subaqueous, bleached, heavy clay, which perhaps upon further study would be found to have such a high content of fine quartz dust and sand that the name heavy loam would better express the texture. The subsoil certainly consists of marine deposits (marine clay, or perhaps sand banks) which give the ground water there a high pH (more than 7). In how far this is noticeable in

31. Jhr. F. C. van Heurn, Hpt. betr. gronden en gesteldh. der Paja Tjitjem (1920).

the surface next to the fresh water now standing on it has not been determined. Perhaps no river deposits of any thickness have ever been deposited on it, in which case there has not been much opportunity for the formation of peat. The entire coastal plain formation gives the impression of being still young. Hence possibly the surface soil has not yet been intensively altered, in which case an acid reacting hydrogen clay has not yet developed. That change will take place in the future, though it is more likely that before regular peat formation can commence the entire paja will be eliminated through the influence of man.

* * * * *

As to the coastal plains along the southwestern coast of Atjeh, very little has been recorded about them in the literature. This indicates that they are very thinly populated. Between Lho Nga (connected with Great Atjeh through a valley, which is to be thought of as a sedimented-up, earlier strait of the sea, now converted into a plain of paddies) and Tjalang the mountains come clear out to the rocky coast. But south from Tjalang the coastal plain begins, which northwest and east from Meulaboh is very broad and extends southeast to the Soesoh River. From there on to Tapatoean and even somewhat farther on the coast is rocky. Then a new plain begins, which widens at Troemon. At Singkel this plain is extensive, and ends at Baros, which is already in Tapanoeli. Unfortunately I have never been able to visit the west coast of Atjeh myself, but in so far as the available maps show, the two big coastal plains mentioned are of the same character. Quite good sized rivers flow out of the mountains (see the rainfall Tables 89, 90) and these streams bring out much silt, sand, and gravel. The rivers build up their river banks, the ocean throws up bars, and between the two exist the shallows, which gradually silt up full, but which until that time carry the character of marsh land and swamps, a formation similar to the "danaus" of Borneo. The natives live on the banks of the rivers and on the high points at the mouths of the rivers, but the "drasland," as the topographic map calls it, is uninhabited and impassable.

Thus the major portion of the soil continues to be under subaqueous conditions. From the Precarboniferous formations of the mountainous back country the rivers can carry out only weathered material. From the Neogene lying behind Meulaboh and Singkel perhaps something better can come, but the sediment which fills the plain cannot be rich. This is also proved by the "condition of settlement," the degree to which the land has been taken into use and lived upon. Extending out from the stream banks of some of the rivers here and there the natives have been making use of small bits of land along the margins of the lower portions, for example along the Meureudoe River. But along others, as the Kr. Seunagan river, for example, (see for example the Meulaboh sheet of the topographic map) no agricultural use has been made of these areas.

This notable difference between the southwest and the north coasts of Atjeh would be very strange and incomprehensible if Mt. Loser, the highest mountain of Northern Sumatra (3,381 m.) were actually a young volcano. While this mountain is not even certainly a volcano, this does not mean that it does not perhaps for a large part consist of old eruptives but certainly in any case it is not a source of great fertility for the surrounding country.

Evaluation and Utilization of the Soil

In agreement with the foregoing is the fact that the plains, the low lands of North Atjeh are practically entirely used for paddies. They are irrigated paddies, where irrigation is by flow (see Fig. 169). Where the farmers cannot lead flowing water onto the fields, the paddies must depend directly on the rain. Of what sort are these paddies? As has been said, the soil itself by nature is not rich; for its nourishment the crop must depend to a large degree upon the irrigation water. Intensive working of the soil is an effective means of making the plant food easily available for the roots. Hence if the rice farmers of Atjeh dig up their paddies with a hoe at

least twice, and sometimes even three times, there is some sense to it. It is not at all a useless custom, but a practice which gives results.

Yet in the different tracts the results are by no means uniform. Here the climate appears to have a noticeable influence. Kreemer[32] records that on the North and east coast the harvest is 30 to 80 times the amount of seed, in Great Atjeh 35 to 45 times, and in the Gajo (lake region) 30 times. If we now calculate that per hectare approximately 19 to 28 kilograms of seed paddy are necessary, then that would mean crops of 7.8 to 31 quintals paddy per ha. for the north and east coast, 9 to 17.5 qu./ ha. for the north and east coast, 9 to 17.5 qu./ha. for Great Atjeh, and 7.8 and 11.7 qu./ha. for the high-lying inland. Then if we compare these figures with the certainly lower yields of the west coast, then we come back to the old rule, which also appears to be true for Atjeh: The more rain, the lower the yield. To show this it is but necessary to place the above-recorded yields along side of the corresponding tables showing the distribution of rainfall (Tables 89-93).

If these rough estimates are checked more carefully by exact experimental cuttings, the results will indicate how in the future the rice production of Atjeh can be insured and increased: in the first place by regulating irrigation well on the north coast and in the valley of Great Atjeh on out to the sea, and as far as possible to convert into irrigated paddies those as yet dependent upon the rain, and through careful selection of the best rivers as to their water and sediment, to so use their water that not an unused drop of the best quality water and silt flows into the sea. In this way Atjeh can perhaps continue for still a long time to export an important rice surplus to other regions of the Archipelago. The not more than moderate fertility of the soil of the coastal stretches referred to is compensated for by an intensive cultivation of the fields and by a rainfall of approximately 1.5 m. distributed advantageously throughout the year.

In addition to the above factors there is also something to be expected here from the use of fertilizers. Experiments in Great Atjeh[33] showed increases in yield of from 10 to 29 quintals, and from 18 to 30 quintals per hectare dry paddy by using ammonium sulfate plus double superphosphate, each at the rate of 200 kg. per hectare. There appears to be a serious lack of nitrogen as well as a significant deficiency of phosphorus. Further figures have not yet been published. There is no doubt, however, that also on the north coast such increases of yield are to be obtained at a number of places. It seems to me that not until considerably later will the eastern and the southwestern coast soils be tested as to their fertilizer needs.

In the low lands of Atjeh, maize and upland (kaiñgin) rice play only a minor role. The inhabitants have paid much more attention to money crops such as pepper, areca nuts, coconuts, rubber and patchouli (Pogostemon, see page 446).

The cultivation of pepper (Piper nigrum) principally in the plain on the dry, somewhat sandy, occasionally flooded soils along the rivers has been especially expanded (see Fig. 171, page 444) and has brought to Atjeh a prosperity unknown in previous years. It is true that the pepper gardens are not so intensively and finely cared for as are those of the Chinese on Bangka, but here the cultivation has the advantages of a more fertile, younger soil and of a more favorable climate than on Bangka, so that after all a sizeable harvest is obtained. With great care the native of Atjeh chooses a location for his pepper garden. By preference, it is forest land and in selecting this, particular attention is given to the kinds of trees which stand on the land and which indicate the nature of the soil. A number are indicators of favorable conditions, a few others of unfavorable ones. If no forest is standing on the land, then rushes, Cyperaceae, etc., are indicators of bad drainage and are a bad sign. But perhaps good drainage can even make such terrain suitable. Heavy soils rich in clay make the pepper vines grow well vegetatively, but they yield too little pepper. Such soils are thus better

32. Kreemer, l. c., I, p. 459.

33. Afd. Landbouw (Buitenzorg), Jaarversl. (1929), p. 255.

Fig. 171. The Pidië plain, Atjeh. Railway line through quite good pepper gardens along the north coast, on river deposits made up of volcanic material, no longer flooded.

Fig. 172. The Pasè region (Lho Seumaweh) of the northern coastal plain of Atjeh, where the railway runs through areca palm gardens.

used as paddies.[34]

Since there is so much limestone in the mountains of Atjeh, we should not expect such strongly leached "hydrogen clay" as we mentioned in the discussion of Bangka soils. Hence "soil burning" as a remedy is also superfluous here in Atjeh. Through drainage sour soils eventually become good though this does not make them rich.

Any close correlation between the occurrence and productivity of pepper gardens and the soil type has not yet been established. However, it does seem probable that such a relationship exists. If this could be worked out it would presumably be of value for the future.

Perhaps at the same time we could learn on which soils areca (betel nut) palms, another important crop of Atjeh, grow the best (see Fig. 172, page 444). As yet we know even less about the soil requirements of the areca palm[35] than for example about those of the coco. It is a question as to whether anyone has ever given any thought to these matters.

Since they supply an important foodstuff, coco palms are grown more or less everywhere in Atjeh. However, there are proportionately more in the low land, upon the recent and former ridges of sand marking old beach lines. Cocos also grow in the interior on the sandy banks where the river overflows, and on the reddish brown lixivium soils without sand, in which case the iron hydroxide takes the place of the sand in making the soil loose and pervious, especially for air. Relating to the production there are no figures in the literature. It is true that Kreemer[36] recorded that "in Great Atjeh the conditions for growth seem to be less satisfactory, since the soil consists of heavy clay, which is only slightly pervious and hence is difficult to work";--"periodically the coco palms become yellow" which Kreemer ascribed to a lack of oxygen in the soil. However, there may also be another cause for this, especially since further on he speaks of scorching east winds which in the valley of Great Atjeh cause the fall of a great number of recently-set coconuts. A study of the soil, especially if the soil climate be included, would most probably throw some light on this question.

Cabo negro palms (Arenga pinnata) are found scattered everywhere, both in the jungle as well as in the house yards. Hence these palms give no indications as to the nature of the soil; they desire only a continuously well-drained soil. As for that matter so do the coco and the areca palms.

Nipa (Nipa fruticans) and Sago palms (Metroxylon) on the contrary prefer amphibian and subaqueous land, the former with brackish water, the latter with fresh water. Nipa "palms" occur especially on the widened-out marshy river deltas of the east coast of Atjeh. On the contrary there are more sago palms on the southwest coast, especially behind Singkel, a fact which is apparently connected with the repeatedly occurring scarcity of rice. These palms are thus a sort of emergency help to the inhabitants, which makes us think of the similarity of this country with what we have seen of the poorer strips of Ceram and Halmahera. Certainly there is no lack of water for rice, but whether fertilizing these paddies will bring about important changes in the economic relationships of the inhabitants is still vague music of the future.

Apart from the nipa, the other vegetation of the swamp forests along the north coast and especially along the east coast from Idi to Langkat, is by no means without value. Of the mangrove vegetation the Rhizophora supplies tanbark, besides fuel; Bruguiera spp. give better tanbark, and structural timber as well as fuel; Ceriops spp. and Carapa spp. supply tan and dying barks. The soil of these forests, practically entirely weathered subaqueously, is grayish white. On the side toward the land the water flowing over the submerged soil is brown and acid with a low pH; while farther out toward the sea the water is more and more brackish and with a higher pH. The conditions for the formation of peat are thus not more than moderately

34. Cf.: J. H. Heyl, De pepercult. in Atjeh en Onderh., (Kotaradja, 1912), p. 6. Various points are incorporated in the Government publication: De pepercultuur in de Buitenbezittingen (Batavia, 1913), p. 74.

35. Cf.: Kreemer, l. c., p. 173.

36. Kreemer, l. c., p. 165.

favorable. Only in a few more or less cut-off places can the water become so free of salt and so acid that peat commences to accumulate.

Among other crops, especially commercial ones, which also deserve mention is nilam or patchouli cultivation which is carried on practically exclusively along the southwestern coast, in the vicinity of Tapatoean and Bakongan. Why these occur only there and practically nowhere else in the Archipelago, if we except a few European plantations on Java, is not known. Unless we accept the following statement[37] as positive fact, the special soil and climatic requirements of this plant (Pogostemon) are not known: "In West Atjeh they plant patchouli preferably on virgin, humus-rich loose soil, however also on old kaiñgins, hence where the humus content is already decreasing and the soil is not so loose in structure." As to accuracy and precision, this statement leaves a great deal to be desired. Elsewhere the same writer says "nothing is done along the line of cultivation of the land or fertilizing." Thus it is still a primitive culture. Whether this crop will tolerate a more intensive type of cultivation is another question.

In all Upper Singkel, in the old forest, Dryobalanops aromatica, the tree which produces camphor and camphor oil, still occurs. But we do not know on which soil, nor on which parent rock, nor in which climate, nor at which elevation it grows best. It occurs nowhere else in the entire Archipelago. Is that to be ascribed to a certain delicacy of this tree or to an accident?--Who can say?--at the present time since the synthetic product is purer and cheaper the Sumatran product is of no importance economically.

And now we come to Hevea rubber the planting of which has been extended especially in Langsa and Tamiang, Northeastern Atjeh. In the dry plain and the low rounded Neogene hilly land there was still enough good land either unoccupied or only thinly settled, so that the inhabitants did not wish extra land. These lands were more easily available for rubber especially since they are not fertile enough for more exacting crops. The soils had been formed from deposits of rivers such as the S. Simpang Kiri and the S. Simpang Kanan, coming from regions consisting predominantly of old and young Tertiary sandstones, loamstones, claystones and some limestones. To the formation of these soils eruptive rocks have not contributed to a degree worthy of mention. But Hevea is a tree which does not demand much. It grows if only it has but enough water and air in the soil; thus here its cultivation succeeds excellently.

If the world could but use several times as much rubber as it has need of today, cultivation of Hevea in this region could be greatly extended without limiting the area of other crops.

Oil palm plantations are also found in these regions. But very much earlier this tree crop shows definitely a need for fertilization, since in connection with the setting of fruit it draws significantly more plant nutrient materials from the already too-poor soil. Then in the bunches of fruit these nutrients are carried out of the garden.

* * * * *

3. THE BATAK REGIONS

According to soil, landscape, inhabitants and culture the Batak Regions form so much a single whole that they deserve to be treated in a separate chapter. Administratively they are now divided into two districts. The larger part belongs to Tapanoeli, while the Karo lands and Simeloengoen are under Sumatra's East Coast. But for our purposes in which we are considering the soil it appears preferable to keep these subdivisions together. On the other hand in connection with the European crops of Sumatra's East Coast, there are various other things to be said about Simeloengoen which will be given in the following chapter.

Soil-Forming Rocks

As has already been touched upon in the general consideration of Sumatra

37. H. Loos and H. Gonggrijp, Patchoeli, Landbouw 2 (1926-'27), p. 335.

(see page 418), the outstanding characteristic of the rocks of the Batak Lands is the predominating covering of liparite, occurring in the form of loose and more or less hardened tuffs.

At present the most acceptable conception concerning the origin of this material is the following: At a certain instant[38] from one or more points, lying in or near what is now Toba lake, through explosions exceeding all human conception as to violence and magnitude, enormous quantities of fine volcanic ash were blown out and scattered over the surrounding region. In this way over an area roughly estimated at more than 20,000 $km.^2$ the previously existing landscape was buried, not under a harmless layer of snow averaging but 50 cm. deep, but under an ash layer averaging 100 times as deep.[39] The depth decreased in proportion to the nearness to the circumference, for near the edge it amounted to only a few meters or less, while close to the central point of the explosion the thickness is hundreds of meters.

But even from the beginning there were other variations in this covering layer. Of course the earlier buried landscape was not flat, rather a mountainous region with peaks and canyons. Where the slopes were steep the ash soon began to slide off, so that for a time the new surface came to be flatter than the original one. Through erosion and forming of lahars rainwater markedly aided in a process we have learned much about from the volcanoes of today, as for example the Kloet. As a result of this erosion of the loose ash a number of high peaks and ridges were again entirely exposed, while on the other hand the earlier ravines were washed full. Moreover in the lower land, lying further from the center of eruption, where first but little ash had fallen, an extensive, secondary covering of ash was built up, so that while at first the relief of earlier times was practically entirely obscured from the eye, yet from that time it gradually began to be recognizable again. In this work the rivers helped especially. Since the catastrophe they have gradually but continuously cut their channels deep into the ash and tuff and in so doing have again exposed at a number of places on the walls of their deep valleys what had been hidden from earlier times under the liparitic ash cover. In the paper by Druif, cited above, the reader can find much detail regarding this.

Restricting ourselves to the soil-forming rocks of the Batak Lands, we have thus: (1) The liparitic tuff cover, which in places lies hundreds of meters thick (see Fig. 173, page 448), in others only a few meters or still less, and in still other places it has been completely washed away. (2) The older rocks which have been again exposed to the light of day. (3) Volcanic products younger than the liparitic cover, where these products have subsequently been spread out on top of the liparites or have been built up into a number of young volcanoes, of which the Sinaboeng is the youngest and most striking example.

As to the older rocks referred to under (2) these are to be found especially in the northwest, in the eastern part of the Wilhelmina mountains, as well as the old (Permocarboniferous) sedimentary rocks which have been extensively exposed in parts of the Heutsz mountains. There are slates with a more or less silky luster and sandstones, both coarser and finer, more or less quartzitic. Limestone is in the background though it is more in the foreground in the Heutsz mountains. Also here and there a little granite is exposed.[40]

More to the east along the northern edge of Toba lake these rocks are first invisible, covered by the liparitic tuffs. At Prapat, however, they just begin to appear again and then in the Simanoek mountains and their outliers toward the east these older rocks stick out above the liparite. Occasionally remains of the cover still lie in basins and valleys, to approximately as far as the Bila river.[41]

38. In this case a "geological instant" is meant which might have been but a few hours, or some years or even a much longer time.

39. Cf. J. H. Druif, Inl. geol. Deli, Meded. Deliprofst. 75 (1932), p. 95.

40. Cf.: J. Zwierzycki, Toel. geol. overz. kaart N. O. I., bl. I, Jb. Mijnw. (1919), Verh. I, p. 26 and 29 (1922).

41. According to what Dr. Druif told me verbally, though this is different from what Zwierzycki's map gives.

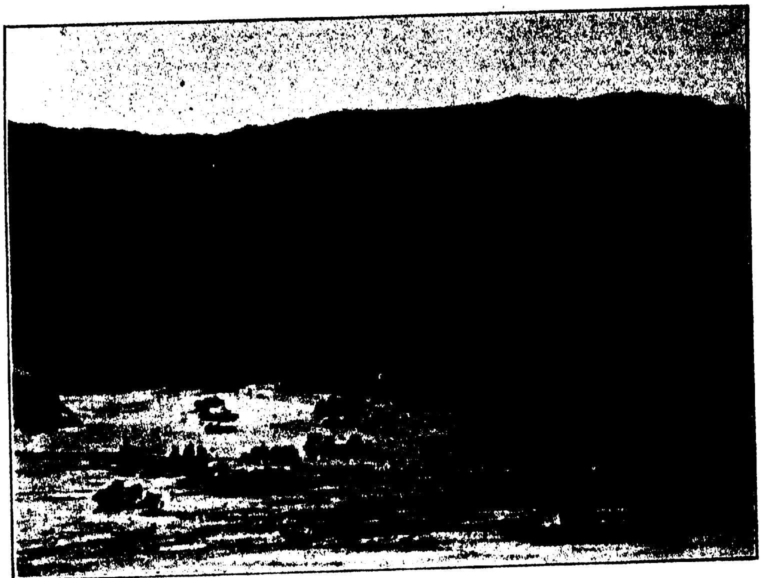

Photo by Tassilo Adam

Fig. 173. Bluffs to the southwest of the Toba Lake. From somewhat below the summit of the tuff walls which are about 300 m. high, there flow out clear brooks. These are fed by the rain water which had percolated down through the porous liparitic soil to the cemented layer. In the distant portion of the plain is sandy colluvium; in the foreground is loamy alluvium, with many villages and paddies. On the slopes no cultivation.

As contrasted with their composition in the mountains of Atjeh, these older sedimentary rocks are lacking in diabase tuffs. The pre-liparitic landscape also appears to have had a number of younger volcanoes, the peaks of which stick out above the liparite cover, both on the Karo-Batak plateau and on the Toba plateau. In addition it must apparently be accepted for other volcanoes that the time of their activity was more or less simultaneous with that of the great liparite eruptions. And finally there are volcanoes which have been active more especially subsequent to these liparite eruptions and so have covered over the liparitic tuff with their ejecta.

This last certainly applies to the Sinaboeng and various other volcanoes of the northern edge of the Karo Lands, lying toward Deli and Langkat, as well as to the Loeboek Raja in the south.--Regarding the D.[42] Saoet, the D. Nagodang, the D. Mertimbang and D. Sitarindak it is uncertain whether they belong to this group, which was already erupting alternatingly with the great liparite eruptions and even still later. The same is thought to be true of the D. Piso-Piso and the Singgalang, to the north of Toba lake. But the row of volcanoes: D. Batoe Harang, D. Imoen and D. Sibadak, as well the D. Tolong and the D. Pamindi, all lying on (or should we say in?) the Toba Plateau, impress one very strongly that they were buried by the liparitic tuff after they had become extinct.

It is clear that only important eruptions after the great liparite catastrophe can be of significance in soil formation. For of course only younger volcanoes can spread out their products as new parent material for soil formation on top of the liparitic (tuffs). And although Volz,[43]

42. "D" is the abbreviation for "dolok" (Batak) = Mountain).

43. W. Volz, Nord-Sumatra, I, Die Batakländer (Berlin, 1909).

and also Bücking[44] collected and had analyzed basic igneous rocks from the foot of the Piso-Piso and Singgalang, it is really of no consequence for us to consider these analyses, since these rocks are to be met with only in very restricted localities, for example on the steep slopes near the Toba lake. Hence they play no role on the upper surface as a whole. Of the rocks of the Loeboek Raja which have given rise to younger coverings of considerable extent, I have not been able to find any rock analyses in the literature. Also of rocks of the young volcanic complex in the northwest which is responsible for the present day soils of Deli, Langkat and Serdang, astonishingly few analyses have been made. From the D. Similir, the C. Pertjibalan and the D. Simatjik, for example, we find nothing; and even from the volcanoes D. Palpalan, Sibajak, Baros, Tinaroh, Meroebai and perhaps still others, distressingly little. From the D. Palpalan we have one analysis of propylitized biotite-hornblende-andesite (Table 18, page 30 under heading V.)--Found on this same mountain Stegmann[45] also mentions "quartz-containing hornblende andesite" and a "quartz propylite," but he gives no analyses of them. Then a couple of cobble stones, sampled by Volz, one a propylitized hornblende dacite from the Lau Soelkam river and the same kind of hornblende andesite from the Lau Toekam river, both of which streams empty into the Wampoe. Afterwards a few biotite-containing hornblende andesites from Soembo-Ikan pass to the west of the Sibajak, however, without chemical analyses so that we have no way of knowing whether these really belong to the Sibajak, rather than to either one of the other volcanoes Pertjibalan or Simatjik. From the Boeloe-Nipas pass,[46] to the east of the Sibajak, Stegmann records also a biotite-hornblende-andesite and a "quartz trachyte andesite" (see Table 18) but no analyses are given. It is uncertain whether these rocks have really come from the Sibajak or from the D. Baros, or from somewhere else. Only one sample, a biotite-containing hornblende andesite (with analysis on page 441), is definitely recorded as coming from the Sibajak.

There have also been described a (metamorphosed) hornblende andesite and a metamorphosed pyroxene andesite from the Koeta Bajoe pass which is on the present day highway between Bangoenpoerba and Seriboedolok. But also in this case we do not know whether the samples belong to the D. Simatjik or really to the D. Baroebai.

Regarding the youngest volcano, the Sinaboeng (see Figs. 174 and 175, page 450), there is no need for us to be in doubt. This erupted only andesite (analyses: see Table 18, page 301).

Meanwhile from all these uncertainties we can make out one thing: the complex of volcanoes referred to most probably erupted both quartz-containing dacites and quartz-free andesites. Druif[47] however mentions only dacites, and then regarding the material which is scattered near Deli etc., he says: "Presumably first one and then the other, ash and dacitic tuff, came from one complex of younger volcanoes, to which perhaps the present day ruins of the Sibajak may also be considered to belong, and that is just about all that we can say about it!"

But with that inadequate evidence, however, we can hardly let the matter rest. A detailed survey of the entire border mountains between Deli and the neighboring regions in the north and the Batak plateau in the south, followed by an extensive series of mineralogical and chemical analyses of rocks most certainly are a necessity which ought to be carried out as soon as possible.

Just a few words about the liparite, or quartz trachyte, as the rock was earlier more often called. In 1892 Wing Easton[48] studying in the field differentiated geographically and petrographically two quartz trachytes, an older and a younger.

44. H, Bücking, Geol. N. en O.-Sumatra, Samml. Geol. R. Mus. Leiden, VIII (1912), p. 1-101.

45. H. Stegmann, N. Jb. Min. etc., Beil. Bd., XXVII (1909), p. 401-459.

46. Neither the Soembo Ikan pass nor the Boeloe Nipas pass, localities apparently ascribed by Volz to Stegmann, are to be found on any of the newer maps; not even on Volz's own map.

47. Druif, l. c., p. 98.

48. N. Wing Easton, Geol. verk. Toba-landen, Jb. Mijnw. (1894), Wet. Ged., p. 99-163.

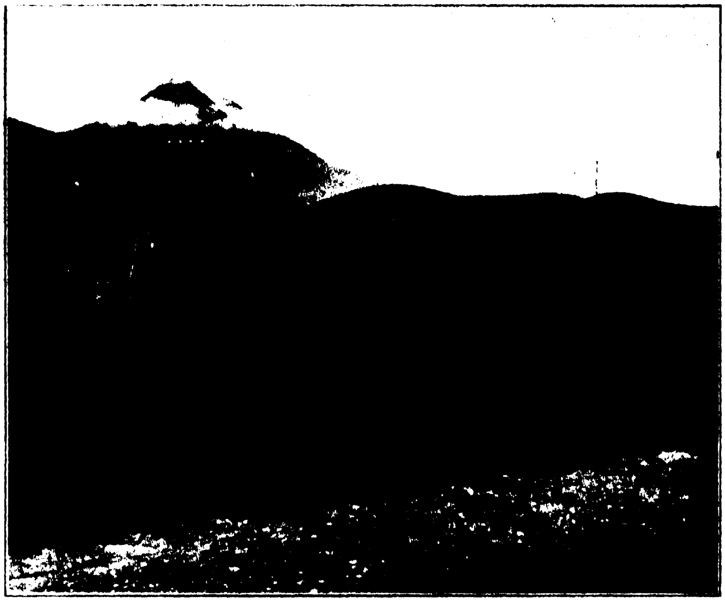

Photo by L. Ph. de Bussy

Fig. 174. Hummocky topography of the tuffs on the Karo-Batak plateau. In the foreground cogon (Imperata), then an upland rice field with scarecrows, then again cogon on the knolls beyond; in the extreme distance is Mt. Sinaboeng.

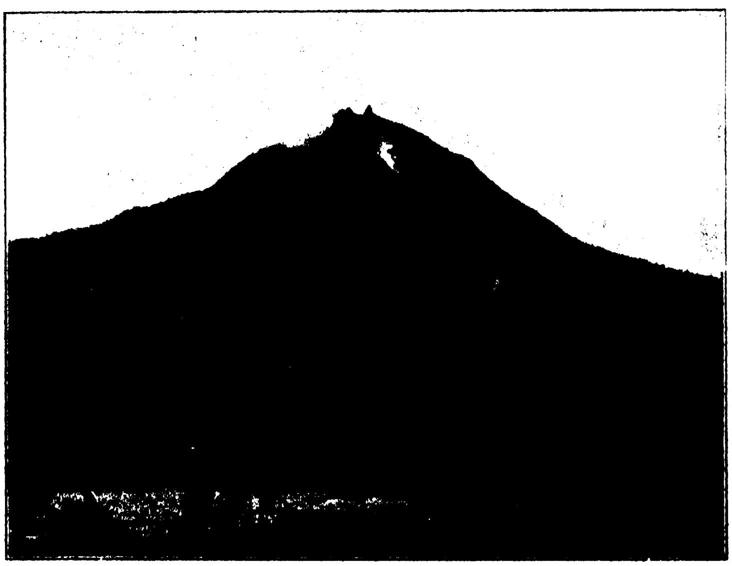

Photo by Tassilo Adam

Fig. 175. Sinaboeng volcano in the Batak Plateau. Top bare; in a crevice are solfataras. Lower, a tropical high forest zone; below that the forest has been kaiñgined off, and is now a cogonal. Still lower are villages, hid in an abundance of trees. In the foreground are paddies. (See p. 456.)

According to analyses by Vermaes,[49] the silicic acid content of the "older" type varies between 68.79% and 72.09% SiO_2 and that of the younger between 71.52% and 77.99%. However the mineralogical analysis of Retgers[50] relating to these samples, throws no light on the matter; he does not refer to the above-mentioned differentiation. Also Druif, in his frequently referred-to paper, although he certainly differentiated three sorts of dacite, mentions only one kind of liparite and liparitic tuffs. It occurs to me that a study similar to that carried out by Verbeek and Retgers[51] on the Krakatau ash, if applied to this liparite material collected from widely distributed localities, would perhaps supply much interesting data in connection with the important cultivated and plantation crops which are grown on the liparitic soils.

Especially quantitative determinations of the mutual relationships of the principal minerals: quartz, sanidine, plagioclase, mica, green and brown hornblende, hypersthene, apatite and glass, and the chemical analysis of these separate minerals would perhaps give very valuable results. If no earlier opportunity arises then perhaps when the "mapping of Sumatra" is undertaken in the direction of Tapanoeli and Sumatra's East Coast, all of the here-mentioned desires may be fulfilled.

There is still one questions which is pending or at least not yet clearly settled, namely: While we learn from the work of Druif how far the loose eruptives from the above-referred-to complex of volcanoes, younger than the liparite, extend out toward the north, (and the mapping which he now has in progress will throw sufficient light on that) yet we still do not know how far the younger and youngest coverings extend out toward the south.

In 1892 Wing Easton had not been there. Volz sketched the limits of the andesitic and liparitic tuff cover "quite schematically"[52] approximately along the Lau Biang. Zwierzycki, on the contrary, seems to have been of the opinion that the limit was much more to the north, lying against the volcanoes, thus considering the entire plateau liparitic. So it is to be read on his map,[53] and in his explanation we find:[54] "The last eruption of the Sibajak and the Sinaboeng have produced andesitic rocks," a statement which we might paraphrase as follows: thus no ash and no lahars, at least not toward the south.--Schürmann,[55] however, again confirmed the opinion of Volz in the following words: "Toward the south the Sibajak-Sinaboeng cover of tuff spreads out, which gradually becomes thinner to as far as the road between Kabandjahe and Kandibata at the bridge over the Lau Biang." Thus Brastagi and its surroundings most probably lie upon a strip of weathered andesitic or at most dacitic tuffs running east and west. But it is also possible that the older liparitic tuff cover was also to an important extent already cut into by gully erosion, so that when the younger eruptions occurred, lahars of a more andesitic nature filled up the previously formed valleys and only to a minor extent flowed outside of them. In short, quite a number of points about this region still remain to be investigated.

This is also true of the plain of Silindoeng and environs, where the limits of liparitic and andesitic parent material have been only "schematically" designated.

Climate

The Batak Lands are high, not only here and there in peaks and ridges such as the mountains of Atjeh; the entire Batak region has an elevation of between 900 and 1,500 to 1,800 m. with occasional peaks sticking up still much higher, to as high as 2,400 m. Consequently the temperature though warm, is but seldom hot. As a

49. S. J. Vermaes, In the above mentioned treatment by Wing Easton: p. 159.
50. J. W. Retgers, Liparieten van Toba, Jb. Mijnw. (1895), Wet. Ged., pp. 99-107.
51. See pp. 22-25 of this book.
52. W. Volz, Die Batakländer (1909), p. 385.
53. J. Zwierzycki, Geol. Overz. kaart N. O. I., Arch. 1:1,000,000, bl. I.
54. Idem, Toelichting, Jb. Mijnw. (1919), Verh. I (1922), p. 71.
55. H. M. E. Schürmann, Ged. not. Bataklanden, De Mijningenieur, 11 (1930), pp. 197-200.

whole the climate is rather temperate to cool. Regarding the climate of these regions Braak[56] records various particulars: "Keeping in mind the fact that for each 100 m. difference in elevation the temperature changes approximately 0.6°C, we may take it for granted that the observations relating to the temperature, moisture and sunshine, which have been made at Seriboedolok (1460 m. elevation) will in general apply to the entire Karo and Toba plateaus"; and then he adds the following figures:

air temperature at night, about 15°
" " at midday, " 21°
daily average 17.4°

On the shores of the lake the daily average is about 20°. But at 2,000 m. elevation however it is only 14°C. Although no soil temperatures have been obtained directly on the plateau we may safely state that since the yegetation consists largely of cogon (Imperata spp.) and ferns, because there is almost no forest, the soil temperature throughout the year will average a good 3°C higher than the air temperature to a depth of about 1 m. It will thus average about 20°C. Under cogon grass near the lake shore the soil temperature will rise to 22° or 23°; while under forest at 2,000 m. it will average around 14°.

During the night the relative humidity of the air regularly rises to about 98%, so that there is much fog, but during the day the humidity falls to about 68%, though that also is but for a short time. With fiercely dry winds the figure can drop to 35%, although this is an extreme. In general it is not nearly so dry.--It rains (see Tables 91, 92) the whole year round with a barely perceptible relatively dry or rather a relatively less rainy period. Indeed, the rain does not fall in very heavy showers, rather it rains very frequently. There is also much drizzling rain. Consequently the total annual precipitation remains mostly under 2 m. relatively much of which can penetrate into the ground. The very porous liparitic tuff also gives every opportunity for this. After the rain, however, the surface soil, in so far as this carries no forest, dries out quite rapidly.

Weathering Processes and Resulting Soil Types

Let us begin with the most important parent material, the liparitic tuff. As to its mineral composition we must presumably make some differentiation quantitatively, although qualitatively, that is to say, according to the nature of the minerals, the composition is apparently everywhere approximately the same. It is then a question as to whether, besides the crystals of quartz, sanidine, plagioclase, mica and hornblende, there is much or little volcanic glass and whether this occurs as fine porous pumice stone and also as fine ash, or rather as coarser, compact fragments of glass. Of course the pumice stone and fine ash weather much farther and much more easily than all other constituents, and so are the first to bring about the conditions making it possible for vegetation to develop on the soil. Taking it as a whole in proportion to the compact crystals and glass fragments the content of rapidly weathering ash and pumice stone is relatively large. But it would indeed be very surprising, if with these eruptions of liparite something similar had not occurred as with other eruptions such as, for example, those which in the last century from beginning to end were observed by man, from which it was learned that the fragmentary ejecta, which fell close by the point of eruption were heavier and coarser while at greater distances there were smaller and smaller proportions of the coarser and the specifically heavier parts of it.[57] Also after the Kloet eruption of 1919 White and I[58] established the same relationships. At the same time, as appears from the analyses, we found that the ash which had fallen at a greater distance must have had a larger content of fine glass particles.

If a similar sorting by the air had

56. C. Braak, Klim. v. Ned.-Indië II (1929), pp. 63-73.
57. See p. 25 (Krakatau ash) and pp. 36-37 (Kloet ash).
58. E. C. J. Mohr and J. Th. White, Ie Verg. Vereen. Pr. st. person. (Buitenzorg, Mei 1920), pp. 75-99 (1921).

also occurred here, then here also liparitic ash with a greater proportion of coarser crystals must have fallen nearest to the points of eruption, thus close around and close to Toba lake and still today to be detected on the periphery. At least in so far as mud flows (lahars) and rivers have not confused the picture! This last they have not done, or at least have done much less in those portions which were beyond or scarcely within the reach of such lahars or rivers coming from the nearest surroundings of the Toba lake, such as places which lay behind higher mountains or ridges. For example, it occurs to me that the high land of Habinsaran lying around the lake peripherally, is a case in point. In the first place, somewhat finer ash settled down there, and in the second place no coarser ash could be washed onto it as a result of erosion elsewhere. It is still not possible to give proof of this, since analyses are not available, and not even any recorded observations are at hand. It is only astonishing that the land in Habinsaran not occupied by the natives is so much richer in forest than that on the plateau around the lake and, in so far as it lies at the same elevation, this should be an indication that from the beginning the soil had had a higher water holding power which had also been intensified by the more rapid weathering of the finer ash. But without local study we have to be content with this vague hypothesis.

The mineraological analyses by Druif[59] do indeed give one clue relating to the differentiation of the liparitic tuffs. The very heavy minerals magnetite, ilmenite, amphibole and even biotite are notably more abundant in the samples from Prapat, Sipige (near Balige), along the Dairi highway and between Wampoe and Bohorok, than in all other samples, for the greater part coming from Deli or Serdang. The first three localities are close to the lake, the fourth is on the Wampoe River which, like the Lau Biang, has its source equally close to the Toba lake. It appears by no means to be precluded that quantitive analyses of the liparitic tuffs, carried out further as to the nature of the minerals, the grain size and the composition would indeed give information of importance regarding weathering, and other matters.

As to the formation of soils from these liparitic tuffs, in the first place they facilitate this in that they are highly pervious. In the relatively cool climate of the Plateau, with no excessive rainfall but yet also without a severe dry season (Table 91, page 422), the weathering is predominantly a subaerial slow leaching, resulting in a pale brown to yellow, sandy lixivium which might also be called a loamy coarse sand if the sand content is quite high, though this is seldom the case.

Where there is no forest, severe erosion occurs, hence there is not much opportunity in such places for the further weathering stages, for senile lixivium.

Between the heavy showers of rain the surface soil dries out easily. Then when a shower does come, it beats loose from the pumice stone gravel the fine loamy and clayey constituents, the products of weathering which are washed either downwards into the subsoil, or away over the surface with the flowing water. They are washed toward the rivers, which transport the eroded material toward the lower flat places around the lake, or by the Wampoe, the Lau Renoen, the Batang Toroe or the Simeloengoen rivers toward the lowland and the sea. In this way the soil tends to become continually sandier, at least so long as it remains quite flat. On slopes, however, the sand also erodes off and has even more or less of a scouring action where it rubs over the surface of the soil--surface or sheet erosion in the optimal form. If the flowing water gathers into a slight depression, then gully erosion predominates (see Figs. 12, 13, pages 134, 176). This becomes more severe as deeper, less weathered and looser layers of tuff are cut into. As a consequence deep ravines or even canyons with vertical walls develop, which then thoroughly drain all the land in their neighborhood which lies higher than their bed, so that in the relatively flat land soil on the top between the ravines the previous favorable conditions for luxuriant vegetation decrease very greatly. All along the edges of the ravines the vegetation languishes or dies and

59. J. H. Druif, Bull. 32 Deliproefst. (1934), Table V opposite p. 56.

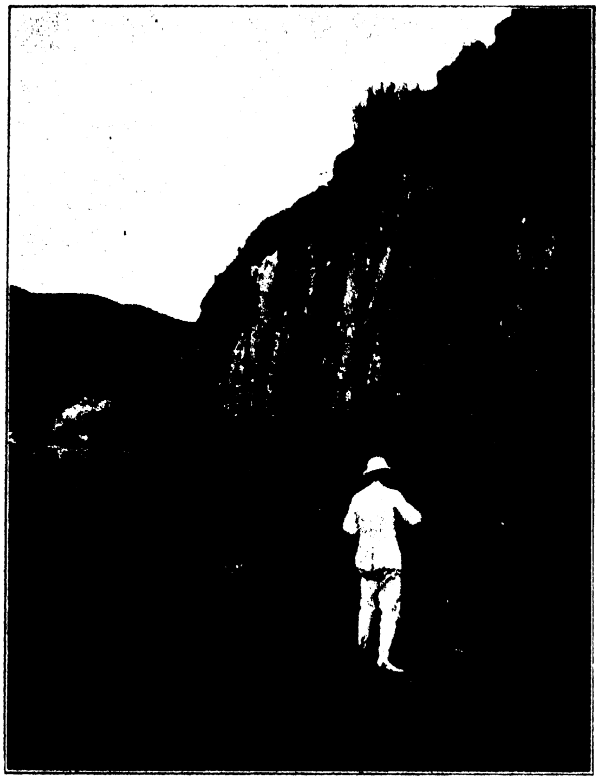

Photo by L. Ph. de Bussy

Fig. 176. Tuff wall near km. 120 along the road between Kaban Djahe and Lau Balang, on the Karo-Batak plateau. Shows the strong gully erosion. Above only cogonal vegetation.

particularly where this happens the banks fall a prey to erosion and the whole landscape seems to take on a more or less bombarded appearance (see Fig. 174, page 450)

Already it has been mentioned that on a tuff with more fine material a brownish yellow lixivium soil with a high water capacity develops. In this case the vegetation is able to endure. A high forest grows up; surface erosion gets less of a chance, but still the superfluous water from outside must get away and there is certainly opportunity for gully erosion (see Fig. 177, page 455). Consequently one finds the deepest canyons with the steepest walls in the forest tracts. Then if the forest be cut down and replaced by low crops, the widening of the gully is inevitable. Simultaneously the previously crystal clear water of the forest brooks and rivers becomes turbid, with beige to brown tints.

Although the climatological conditions for humus formation are relatively favorable, still as a whole the amount of humus which accumulates on and in this soil type is hardly considerable. Where the soil is very sandy and is very pervious, some of the fine humus fragments wash down in with clay and other fine materials toward deeper layers; as a consequence of this, in the profile of such a soil a rather uniformly dark color extends down to a depth of 1/2 to 3/4 m. but since the conditions for the breaking down of humus are particularly favorable, the humus content remains low. If the soil is somewhat richer in fine constituents (the tuff having had a larger proportion of pumice stone and fine ash) then this washing in

Fig. 177. The Bloemei river george in Upper Serdang. Steep and deep canyon cut in the tuff; from time to time the walls cave off into the river. When the tropical high forest is felled the walls and the surface soil erode away.

is less pronounced and the humus coloring is but 1/3 m. or less thick, yet of a more intense color almost a black. This is especially true under a vegetation of cogon and ferns. One should, however, not forget that this black tint makes more of an impression upon the eye than it actually signifies. Earlier when referring to Atjeh (page 429) mention was made of the intense black residue left behind in the soil by certain plant associations, a residue which was really not such beautiful humus as one would suppose if judging only by the color.[60]

In addition to the decomposition of organic matter and washing of humus down into the soil, there is also still another reason which limits the accumulation of humus; namely, erosion, through which much humus from the surface is carried over the surface toward lower less steep lands and there spread out again. As the result of such a phenomenon, sometimes there is an astonishingly thick and intensively colored humus layer in somewhat broader, flat little mountain valleys. Nevertheless this occurs only as an intermediate stage. In a few years or even in a much shorter time this accumulation may again be washed away, or it may decompose.

It may appear surprising at first sight, yet there develops on the liparitic

60. Such kinds of soil with a misleading black surface soil the Germans call "Blender" meaning blinders.

tuff also quite another soil type than the brownish yellow lixivium. In the Dairi lands, along the southwestern side of the Toba lake, the terrain gradually slopes up from the valley of the Lau Renoen to a quite broad ridge of 1,700-2,000 m. elevation, still entirely covered with tropical high forest. The climate there is extraordinarily moist. It is true the rain[61] does not fall in excessively heavy downpours but rather very frequently, throughout the whole year; a great deal of the time it drizzles. In spite of the greater elevation the leaching is intense. On the other hand the decomposition of humus is slowed down, both by the low temperature, and because through the leaching the lixivium becomes much more sour and the pH falls. Thus an accumulation of humus, i.e. peat, can come about. There is also another contributing factor to this result, namely that as soon as once through the leaching the pH has fallen to below 4.5, the iron becomes moveable and goes on out with the percolating water and so the clay remaining behind also becomes paler and less and less pervious, finally quite impervious. The brown peat water can no longer percolate down through the soil, so there develops a marsh peat formation at a high altitude characterized especially by Pandanus vegetation. A couple of species of Podocarpus also occur in the tropical high forest adjacent to such peaty terrains. These trees which are indicator plants of such extremely impoverished soils, have tall trunks with thin, gnarled crowns.

The noteworthy feature of these soils, which may be found in somewhat earlier stages as well as in the virile stage of yellowish brown liparitic lixivium, is the astonishing low content of calcium and magnesium while, in general the potassium content except in a thin layer of very humous surface soil is just as low, and the phosphorus content is also on the low side. Thanks to the untouched tropical high forest, humus and nitrogen are indeed present in considerable quantities, still no one can call this soil type fertile. This is confirmed by the fact that these forested lands, although so close to the relatively thickly populated Batak Lands, are never cleared.

* * * * *

Most of the other parent materials of the soils of the Batak Lands play no important role as soil formers. Only the more basic young eruptives, dacite, andesite and basalt deserve separate attention. On the northern side of the Karo plateau these eruptives, as the youngest geological formation, have covered over the liparitic tuff. Most of these eruptives have now weathered to a young juvenile yellowish brown lixivium but there are also some portions already in the virile to almost senile stage. No longer is much forest to be found on the lower and flatter parts. Actually there is a much larger proportion of cogon (Imperata spp.) and ferns, although there is also much cultivated land, a point to which we will refer later.

Also on and around the foot of the Sinaboeng is found a brownish yellow lixivium, which differs from the similar liparitic lixivium through the absence of quartz, sanidine, and plagioclase crystals, the last of which are on the sodium-rich side. But on the other hand this soil contains many crystals of calcium-rich plagioclase, besides augite and hornblende, as well as iron ore. In short--the particular constituents which are abundant in the basic eruptives. Where the water relationships make it at all possible, this soil type is cleared and used for agriculture. In general, it is more fertile than the soil on the liparitic tuff, because it not only contains more plant nutrient materials, but also because of a greater water capacity the roots have more opportunity to profit from them.[62] (See Fig. 175, page 450.)

Neither on nor around the Singgalang nor the Piso-Piso, nor around the andesitic peaks of the Toba plateau, already mentioned (pages 447, 448), does there occur

61. Observations of a few years taken close to the ridge gave figures indicating an annual average of more than 200 rainy days with more than 5 m. rain per year.

62. Cf: H. C. Bongers, Meded. Landb. Voorl. No. 5 (Batavia, 1920), p. 11: "The very fertile group of paddies around Pajong and Batoe Karang also lie on an old andesitic mud flow from the Sinaboeng."

any special soil which is worthy of separate mention. In the plain of Silindoeng, to begin with the plain of Taroetoeng, there is much allochthonous soil which has come from liparitic as well as from andesitic material. As a rule, at least calculated according to the area, because this material has originated from erosion elsewhere is of finer texture and thus also more retentive of water and more fertile than the autochthonous kinds of soils.

Because both the deeper-lying soil material as well as that washed-on are still too pervious and the rivers lie in ravines which have been cut so deep that stagnating water is practically excluded, the above soils hardly ever take on a subaqueous or amphibian character. Only on the highest spots of the Toba plain at about 1,350 m. does one come upon some swampy and marshy lands with presumably acid humus and acid, peaty, brown water. Under this beginning of peat formation[63] the soil is of course naturally bleached to a sandy, white clay. Thus far however no one has studied this locality more closely.

Evaluation and Utilization of the Soils

Not so strongly as in Atjeh's mountain land are the mountain slopes here in the Batak lands differentiated from the flatter parts of the valleys. But still we may quite well say that in the regions under consideration all lower, flatter portions of the land are valued significantly higher than slopes or plateau land. In the first place this is naturally a question of water, in many places the lower lands are irrigated. Indeed, where even only a little ravine in the Batak Lands can be irrigated, this has been done and the inhabitants have laid out paddies (see Figs. 173, 175 and 178). But where there are too many people in proportion to the available, irrigable land, the inhabitants have also been compelled to cultivate unirrigable land, hence there has been and still is a good deal of kaiñgin cultivation (see Fig. 174, page 450).

Hence it was that in 1890 Westenberg[64] wrote as follows about the then still independent Batak lands: "While some of the rice raised is grown in flooded fields, most is upland rice grown in kaiñgins, since the peculiar terrain hardly permitted the laying out of paddies on the soil of the ravines."--On the contrary Van Hasselt, an old resident, wrote in 1893[65] a "Note relating to the Cultivation of Rice in the Residency of Tapanoeli." He had apparently tried to make his description complete in all respects, yet there is not a word about kaiñgins. For him, at least for the cultivation of rice in the Toba lands belonging to Tapanoeli, there were only paddies. In contrast with this Bongers elsewhere states:[66] "In the low parts of the Karo Plateau, between the hills and along the rivers, where material washed together" (presumably surface soil from higher lands is referred to) "has more or less accumulated, the native of Batak carries on his dry rice culture with but very moderate results." This would imply that there are no paddies at all. Here must be a misunderstanding. Actually in the ravines the rice fields are laid out as paddies. In a season of little rain a large proportion of them cannot produce a crop. But here one cannot expect large streams flowing onto the upper fields, down through them, and away below, as is the case for example in the Preanger or Banjoemas, for an annual rainfall of not even 2 m. (Table 91, page 422) with the very pervious soil does not make this possible. In a season of less rain these mountain paddies are dry, but still they do have, and also receive from the side slopes, always more soil moisture than do the higher slopes and ridges. If no more ravine land is available, kaiñgins are first laid out on these higher slopes and ridges.

The value of the paddy produced and, on the basis of that, of the soil is indeed very variable. These values may also be stated in figures, in which case, however,

63. Also **Bongers** (l. c., p. 11) pointed out the opportunity for peat formation, though he was referring to the highest parts of the Karo plateau.
64. C. J. **Westenberg**, T. v. Ind. T. L. en V. k. XXXIV (1890) p. 10 of the separate.
65. A. C. **Van Hasselt**, T. v. Ind. T. L. en V. k. XXXVI (1893), 31 p.
66. H. C. **Bongers**, l. c.

Photo by J. M. Baron v. Tuyll v. Serooskerken

Fig. 178. Liparitic tuff plateau, east from Lake Toba. Above in the distance poor grass vegetation. Sterile broken faces of the cliffs (cf. Fig. 18, p. 138). Alluvial plain fully converted into paddies, all planted with young rice plants.

the elevation and thus the temperature of the locality must be kept in mind. Apparently relating more specifically to Toba and Silindoeng, Van Hasselt[67] records that "Taken as a whole on the best lands the production per hectare amounts to 17.5 to 30 quintals paddy and on poorer lands 8.7 to 20.2 qu./ha. In one single case from one hectare 43.5 quintals were harvested, which is indeed very unusual."--Without doubt this refers to paddy cultivation.

For the Pakpak lands Ypes[68] mentions "a yield of 40 times the seed paddy planted; this cannot be called splendid, since according to (their) assessment.... at least a 60 fold harvest can be obtained." With the use of 21 kilos per ha. seed paddy these figures should come to about 11.5 to 17 qu./ha.--But this is kaiñgin rice. These kaiñgins on tropical high forest land can be planted to rice 2 to 4 seasons; while on old kaiñgins, however, after a fallow with a growth of secondary forest, at most 2 seasons. Rice growing does not pay for longer periods, although other crops still do.

Loose[69] cites how "according to the returns for 1918, 3,669 ha. in Dairi should produce about 3,088 metric tons wet paddy," which comes to 8.2 quintals per hectare, or approximately 14.8 quintals paddy per hectare of kaiñgin. This agrees nicely with the estimate by Ypes, but--is not high.

In his book "Simeloengoen" J. Tideman[70] records: "Apart from that, under normal circumstances the best lands return 75 times the seed rate, and the poorest 30 times, calculated on the basis of hectares with approximately 1,500 kg. seed paddy."

67. A. L. Van Hasselt, l. c., p. 23.

68. W. K. H. Ypes, Singkel en de Pak-pak-landen, T. Ind. T. L. en V. k. XLIX (1907), pp. 355-642, especially p. 619.

69. H. Loose, Dairi, Meded. Alg. Pr. st. Avros, Alg. Ser, No. V, p. 11.

70. J. Tideman, Simeloengoen, (Leiden, 1922), p. 125.

In the report of the Agricultural Section of the General Experiment Station (Buitenzorg) for 1927 we find the following summary statement:

Table 96

Region	Village	Method of Cultivation	Yields of Wet Paddy Without Fertilizer	With .87 Quintal Double Superphosphate per Ha.
			quintals per Ha.	quintals per Ha.
Toba Plateau	Siboentoean	Kaiñgin unfertilized	14.8	18.3
Toba Plateau	Bahalsingkam	Lowland paddy, irrigated unfertilized	19.15	30.5
Silindoeng	Hoeta barat	Lowland paddy, irrigated unfertilized	27.9	35.8
Angkola and Sipirok	Bandar Sapoelooh	Lowland paddy, irrigated unfertilized	28.7	34.9

Here we see the much larger yield from paddies than from kaiñgins, and at the same time it is apparent that the sedimentary, allochthonous liparitic land of the two last villages is clearly more fertile than the autochthonous soil. As shown in the last column of the above table fertilizing with 0.87 quintal double superphosphate per hectar (1 picul per bouw) markedly increased the yields, making apparent the large phosphorus requirement of these liparitic soils.[71]

In 1929 similar yields were obtained in an experiment at Sait ni Hoeta, subdistrict Dolok Sanggoel, which is on the Toba plateau:[72]

Here also phosphorus appears to be deficient. But when one quintal per hectare double superphosphate has been applied, another factor then seems to be in the minimum, for adding 1/2 quintal/ha. more does not significantly increase the yield. Perhaps it is really the temperature, which may be too low at this elevation of around 1,400 m. above the sea. If that be so, then all attempts to still further increase the productivity of the soil by means of additional fertilizers are, a priori, without avail.

Data for the years after 1929 unfortunately have not yet been published. It is therefore only an unconfirmed impression of mine and nothing more definite than taking soil and climate into consideration, besides a relatively modest phosphorus fertilization, that there is not so

	Yield of Paddy quintals per hectare
Kaiñgin cultivation method--unfertilized	15.6
" " " -- 1/2 quintals double superphosphate	20.8
" " " --1 " " "	23.2
" " " --1 1/2 " " "	24.1

71. Dept. L. N. H., Afd. Lb., Versl. over 1927, pp. 408-410.
72. Dept. L. N. H., Afd. Lb., Versl. over 1929, p. 270.

very much else which can be done to improve the Batak rice culture, and that the yield can be considered to be quite reasonable. That at these elevations of 900 to 1,400 m. still such good yields are obtained, is certainly to a considerable extent also to be ascribed to the relatively low rainfall figures (Table 91, page 422). At similar elevations on the outer slopes of the Barisan chain it rains heavily so that the soils there are to a high degree leached out. Hence the harvests are so much lower that there kaiñgins are scarcely ever made, so that the forest is allowed to remain undestroyed.

* * * * *

If rice is in general the principal crop, a number of other crops are also raised as foods and supplementary foods. The exacting European vegetables and potatoes deserve especial mention. From a paper by Bange[73] regarding the cultivation of cabbages on the Karo plateau, we note that the cultivation of this crop, which is carried on more or less along the highway toward Medan, is limited to the good soils of the Lingga region in the northern part of the Karo plateau: Tongkeh, Petjeren, Keling, and Radjapajoeng, all mentioned as centers of production, lie around Brastagi on andesitic mountain lixivium, very close to the G. Sibajak; while Pajoeng and Goeroe Kinanjan, of which it is said that "the soils are particularly excellent," lie on the foot of the Sinaboeng and these also are on more basic parent rocks. The Baros and Soeka regions, for a large part on liparitic tuff, have "a potato cultivation of limited extent and there cabbage is hardly planted at all." Still more southerly and westerly, thus on liparitic tuff and perhaps also on residual or allochthonous soil of the old Wilhemina mountains (schists, granite), "the Sarinembah and Kota Boeloeh regions are on tracts of little significance for agriculture and gardening." Here the connection between vegetable cultivation and soil (parent rock) is very striking.

Bongers[74] observed a similar relationship "here and there on the southern limits of the Karo lands, the Wilhelmina mountains, are found primary granitic soils--and it is typical that the most delicious oranges are raised on these lands."

Bongers pointed out this relationship, but made no attempt at an explanation. Such an explanation will probably involve all kinds of studies, both of the soil and of the fruit trees. Here only a suggestion may be given. This case reminds us of the differences in flavor of various wines from a single large wine district, lying somewhere in France or on the Rhine. The localities are sometimes so restricted that the difference can hardly be caused by variations in the climate. Thus apparently in some way or another it must be due to the soil. It is of course possible that variations in the quantitative relationships of the most important plant food substances: N, P, K, Ca, Mg, Si, S, and Cl play an important role. Also the water relationships of the plants. But it is not impossible that the trace elements, of which only very small amounts occur in the plant, are of significance here. We think for example of Fe, Mn, Cu, Ba, Mo, Bo, F, Va and perhaps still others. Without closer study who can have an opinion as to the effect of these elements? Regarding some of these elements which are only to be found afterwards in traces in the ash, we now already know that in their complete absence many plants cannot grow and thrive. But neither can we say that all these elements even in traces must have a favorable effect; perhaps in part they are indeed definitely detrimental. And then there is still the question as to what influence they have on the enemies of our cultivated plants, on the bacteria, fungi and the various animal pests? Who knows what future research will give notabl results in this field? However, it is indeed certain that many soil researches and

73. J. A. Bange, Landbouw, II (1927), 627-644.

74. Bongers, l. c., p. 12.

analyses of earlier times were conceived in much too simple a manner, we now realize they are worthless and must be replaced and amplified by new and more refined lines of research.

* * * * *

Finally a few words about the cultivation of coffee and tea. While we find coffee in different places in the Batak Lands, for example in Central and Southern Habinsaran,[75] there is not much of it. Yet the Sipirok coffee is known to be of good quality. Taking into consideration the relatively rain-poor climate in a number of places, it would seem that more coffee, especially C. Arabica, could be cultivated.

In Simeloengoen--about which more in a subsequent chapter when we come to Sumatra's East Coast--the cultivation of tea on liparitic tuff soils is very extensive. Great plans have been cherished for the extension of this crop into the Dairi lands at elevations between 1,200 and 1,700 m. From the previously recorded data (pages 453-456) it is apparent that the liparitic tuff soil is not equally suitable for this crop. The soil must be adequately weathered in order to be able to guarantee an adequate supply of water to the tea bushes. Thus it must not be too sandy. But in the lower zone between 1,200 and 1,400 m. there is more land than already has been taken up by the inhabitants. In the higher zone above 1,600 m., however, there exists the danger of a bleaching of the soil through more or less peaty water, with the result that the soil will become more difficultly pervious and consequently there will be a stagnation of the water movement. The optimum conditions thus lie between elevations of 1,400 and 1,600 m. But there it is only moderately possible to overcome the difficulties of the terrain, in particular the numerous canyon-like cuts, and then only during times of high prices for the crop. Extensive, plantable, relatively flat lands, as in Siantar, are not found here. It is true that lower down there is suitable terrain but there, as previously stated, too many people have settled upon the land.

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4. THE COASTAL STRIP AND HILLY LAND FROM TAMIANG TO BILAH-- THE AGRICULTURAL REGION OF SUMATRA'S EAST COAST

The reason that on Sumatra's East Coast, in contrast with most of the other portions of the Netherlands Indies outside of Java, a number of economically very important crops are cultivated is to be ascribed to the fact that in this region more and earlier attention was given to the soil and the soil-forming rocks, and researches were carried out dealing with these questions. At quite an early period, that is to say a half century ago, a start was made with these. First incidentally and exploratory, in a broad way. After that quite thorough research was conducted although according to different systems. Eventually the general knowledge of the soil was distinctly furthered.

To even briefly summarize all these investigations would exceed the compass of this book. But even a short statement is unnecessary since at the end of his latest publication Druif has given an extensive survey of the literature.[76] In this he has included more than 100 titles which deal more or less directly with the soils of Sumatra's East Coast. However, it is desirable to here indicate the broad lines along which this knowledge has developed.

Let us begin with the samples of tobacco soils from Deli which were studied according to the methods employed in Europe (Van Bemmelen (1890), Van Bijlert (1897-1900)). Hissink made a first attempt (1901) to map the soils of the tobacco districts. He studied the soil samples of his experimental fields entirely according to the methods of the previous century, which to us at present appear quite inadequate and consequently of little value. Vriens and Tijmstra likewise employed similar methods

75. L. Weber, Meded. Encycl. Bur. 1914, III, p. 21.

76. J. H. Druif, Bodem van Deli, II, Bull. Deliproefst., 32 (1934), pp. 160-187.

of research. The many data obtained were empirically worked up statistically and published (1907-1912), but from them it did not seem to be possible to deduce anything of importance or get any real insight into the true nature of the soil differences. Thereafter it was otherwise. The investigators then began to realize that in Sumatra's East Coast are a number of distinctly different soil types, not only different as regards certain numerical values to be obtained from analysis, but actually different in all respects, so that a comparison of the figures resulting from analyses could never give a final basis for evaluation nor for the agricultural measures to be employed. From then on these soil types became gradually more sharply differentiated from each other and there was an endeavor to obtain for each type the knowledge and insight necessary in order to develop the soil management processes and the means to bring these about. This transition period from 1915-1923 is covered by the publication of Van Heurn (1918-1923), by that of Rutgers (1922) and by some of my own papers (1915-1919). The first one to undertake a study according to the soil types of the region on a genetic foundation was Oostingh (1927-1928). His work was followed and amplified by Druif, who in several papers has described in detail the genesis of the soil types and has done it in such a way that upon that foundation further work may be built.

From the general discussion about Sumatra (above, page 418) the reader has already seen that as a whole, in the region to be considered here, completely residual soil types lying upon solid parent rocks never do occur. In so far as there are residual soil types, they have originated from loose material, coming from the mountainous back country. Sometimes that material had already become more or less hardened, (this applies particularly to tuffs). Thereafter these tuffs have again weathered and have become soil. We may thus, if we wish, conceive of the tuffs rather than the loose volcanic material as the parent material for a number of soil types. The loose ejecta had been transported out from the mountains toward the lowland by flowing water, either all at once, as mud flows or moved gradually, and hence usually mixed with other materials.

Soil-Forming Rocks

To find these, or really their origin, one has thus to hunt in the mountains lying behind the region. On a foundation of Tertiary and older rocks, which in the region we are discussing are now practically never found at the surface (pages 446-448), as a result of the great liparitic ash eruption(s) there had been spread out an extensive layer of this material. Now, since the original surface covered over had previously been more or less irregular or cut up, obviously the ejecta in some places accumulated to great thickness while elsewhere it was very much thinner. Especially at that time, just after the eruption(s) numerous lahars (mud flows) rushed down off the uplands, filling up the existing depressions in the terrain and in so doing evened out the surface. The landscape must then have appeared as one enormously great, but very low flat heap of sand with its center, which at the same time was its highest point, somewhere near where Panahattan now lies, above Prapat. This heap of sand sloped off very gradually toward the northeast, toward the sea, and apparently down to and quite into it. But it also sloped toward the northwest, to Langkat, somewhat further on than the present day bed of the Wampoe. There, however, it had thinned out to only a very few meters thickness, and finally to only a few cm. The same was true toward the east, to beyond the present day Asahan, yes even into Kwaloe and Bilah.

Afterwards the previously existing mountain peaks and ridges were washed off more or less clean. Especially that mountainous land which stretches out from Prapat eastwards into Habinsaran; though of course neither the valleys nor the depressions in those mountains were exposed. All the material which was eroded was carried northeastwards by the rivers which formed anew. Their deposits raised the surface of the already existing lowland and a part of the adjacent sea bottom. At the latitude of Sabang liparitic sand has been found to extend out on the present sea bottom to the middle of the Malacca Strait.

Our heap of sand had thus become much altered in form. It had become somewhat lower, and at the same time more or less incised. In the middle, where the thickness may have been several hundred meters, the originally loose ash began to pack down more and more and to harden into tuff, as today it can be observed in the walls of the deep canyons which have been eroded by rivers.

After a period of no eruptions, a time of renewed volcanic activity followed. This time however the points of eruption were not at Toba lake, but more toward the north-northeast, where there gradually grew up the series of volcanoes from the Dolok Simbolon in the east to the Dolok Semilir in the west. While the Sibajak appears to have been the last to have erupted, even yet the historic sequence of their formation has not been precisely worked out.

More important for our purposes than the exact historical order are two facts:

1. All volcanoes of this series have brought to the surface significantly less ejecta than did the liparitic eruption(s), so that the region which they have covered over with volcanic materials is much smaller. Moreover this probably also was done in a calmer tempo. A volcano can, so to say, in one shot fire into the air 1 cubic kilometer of magma, in which case the ash spreads over a great area; on the other hand, it may eject the same quantity of magma during the course of several weeks, or years, and in that case the ash heaps itself up in a much smaller area closer to the crater. Then from time to time during heavy rains lahars (mud flows) rush down and shove far out into the lowland long ribbands of loose lahar material, the particles varying in size from fine ash to large blocks of stone. This latter explanation of the manner of formation coincides better with the observed facts as Druif has described them and indicated them on his map.

2. The composition of the magma and consequently of the ejecta differs from the previously erupted liparitic material, and indeed so much so that the latter become gradually more basic, thus more dacitic and finally even andesitic.

The different lahars which originated from material of different eruptions[77] were from magma of divergent chemical composition and, in consequence, also had a different mineralogical composition. It is this last criterion which Druif used in his study which led to the differentiation of the various lahars.

As has been said, lahars flowing off toward the north from the above-mentioned series of volcanoes left behind long, ribbon-like traces. Also, for that matter the same thing happened toward the south, away out over the Karo Plateau, but in this direction there were astonishingly few mud flows, so that they scarcely reach the Lau Biang. One of the reasons for that is that the points of eruption, and the originally built up loose cones of ash and other ejecta did not stand on a horizontal plain but on the northern slope of the "sand heap" of liparitic ash and tuff.

In their flow the lahars naturally sought out and followed already existing depressions in the land, ravines or broader valleys, and filled these up. And they did more than that: they left the depression with a ridge in it, in the middle it was higher than on the edges. Consequently the rivers could do nothing else but to flow along the boundary between the new lahar and the earlier terrain. Hence, taken broadly, the present day rivers are at the same time also lahar boundaries, although also many a lahar has gone beyond its original boundaries and spread out broadly. In the lowland there are many rivers which here or there have later broken broken across an already existing lahar in order to select another bed which was better suited to it. All this can be read very easily from the map by Druif and explains clearly the genesis and the modifications of the landscapes of Langkat, Deli and Serdang.

After the termination of the period of activity of volcanoes and of the lahars connected therewith, there continued on the slopes only the unremitting flowing off and eroding rain water, deepening river valleys and below in the plain raising the

77. These different eruptions need not necessarily be eruptions of different volcanoes; even a single volcano, indeed, also taps magma "from different vats."

level of the terrain by deposition of the eroded material.

Especially in the deeper portions thick, long undisturbed lahars hardened to tuffs so that only from the surface can residual weathering make its influence felt.

Certainly in the mind of many a reader will now arise the question: why have these different lahars been so carefully differentiated from each other in Sumatra's East Coast, while elsewhere in the Netherlands Indies one has usually been content with merely distinguishing the much more striking differences between acid and basic ejecta, and at most separations only into basalt, andesite, dacite, or liparite have been recorded? Questions such as to whether the ejecta is one or another kind of dacite, which elsewhere in the Netherlands Indies have thus far made no impression are indeed carefully considered here in Deli, since it seems that these apparently unimportant differences in parent rock sufficiently affect the soil originating from them to cause the quality of the Deli wrapper leaf tobacco grown on them to show distinct differences which are very important economically. However, sufficient researches have not yet been carried out on the various phases of this question. These effects occur so regularly that it has even been possible to map the lahars which give high value tobacco and those which do not[78]; still more will be said about this later.

Meanwhile we cannot help but wonder whether, in the same way in the Principalities of Java, for example, the different Merapi and Merbaboe ash eruptions and lahars could be differentiated, and whether in the tea districts of West Java one lahar or lava stream gives a significantly higher quality tea than another. But these are questions which really must be considered when we come to Java.

Climate

Whatever there is to be said concerning the climate of Sumatra's East Coast in the narrower sense is of course connected with the data in Tables 93 and 95, pp. 425, 426.

The land runs up from sea level to 2,000 meters and more. Close to the sea the air temperature averages 25 or 26°C, between the daily limits of approximately 20° and 32°. With greater elevation this decreases to an average of about 12° with a range of between about 5° and 18°C. The soil temperature under tropical high forest, such as has been standing 70 years, does not depart much from the average air temperature. Close to the sea it is about 26°, and at 2,000 m. elevation about 12°. But where the forest has been displaced by cogon (<u>Imperata</u> spp.), these temperatures must become a couple of degrees higher, and in well cultivated fields a good 3.5° higher. Thus on the so-called lower plantations soil temperatures average about 29 to 30°, while above 800 m. elevation in well cultivated ground the average soil temperature falls to below 25°C. The reader should also compare pages 42-45 of this book.

As to the rainfall, Boerema[79] had devoted a separate work to the northwestern part of Sumatra's East Coast. To avoid repetition the reader is referred to that publication. Also Braak records in his handbook[80] a number of data relating to the rainfall. All these data, however, refer more to the atmosphere than to the soil. Even so, a few significant details are to be culled from them: Although the number of rainy days for Medan per year might be 142, thus be almost 40% of the year, the number of minutes per year in which it rained was only about 5% of the total number of minutes, i.e. 95% of the time it is "dry." In the true rainy months the percentage of rainy minutes may increase to 10, while in the "dry" months, as February, it falls to less than 1%.

In connection with the nature and the surface position of the soil of an agricultural region such as Deli, it is important to know what proportion of the rain is taken up by the soil, and how much runs off over the surface. There are no data expressed in figures regarding this,

78. See: S. C. J. Jochems, and C. H. Ten Cate, Ind. Merc. LV (1932), p. 561 and E. C. J. Mohr, Ind. Merc. LVI (1933), p. 227 (with a small map).

79. J. Boerema, Verh. Kon. Magn. en Meteorol. Observ. Batavia, No. <u>11</u>, (1923).

80. C. Braak, Klimaat v. Ned.-Indië, II, pp. 26-53.

but one ought to be able to collect such with but little difficulty particularly where, as at Medan, is installed a Hellman self-registering rain meter (pluviograph). This could be done as follows: with watch in hand during each heavy shower, note down the minute when water commences to flow over the surface; from the pluviograph then read for this minute how many mm. of rain had already fallen, being the amount the soil already had taken up, also note how long it had rained altogether, and what was the intensity of the rain. Observations such as these are cheap and simple to make and if carried out over a considerable number of years would appear to be of much practical value. Obviously the results would be of value only for the soil type and the vegetation, etc. where the pluviograph stands.

At Medan the evaporation is also measured[81] with an open pan evaporimeter. In this way the total annual evaporation has been found to be roughly 900 to 950 mm. Since there the total rainfall is around 2 m. annually, there then remain about 1,100 mm. for runoff and percolation. Now it would certainly be of importance to learn what happens to these 1,100 mm. This is possible only by experiment, and through experience and observation.

Already generalizations regarding "the fate of the rain water" have been stated on pages 53-55. Since this is such an important agricultural region, to amplify that discussion we may well here add some points. From experiments at Buitenzorg[82] it appeared that one may reason along general lines thus: In a certain sense each shower is to be considered by itself. Hence there is mention of a certain rainfall limit, at Buitenzorg, and for the soil there measured it is about 5 to 7 mm. while the rest flows off. If during the previous days it had also rained heavily, then the limit falls to sometimes as low as 3 mm. After long drought the limit may rise to 10 mm. and even above and yet nothing runs off. For Deli it is now necessary to determine the limits for the different soil types and under different conditions in which they may exist, such as: clean cultivation, under cogon, under parang (cogon with some scattered fire-resistant trees), under tropical high forest; with different slopes; and with different intensities of rainfall. The value of these limits is then that one knows at least approximately that, as for example in a month when 200 mm. falls in five showers of 40 mm. of that rain at the most 5 (showers) x say 8 mm. (rainfall limit) = 40 mm. rain soaked into the soil to do it and the plants good, while 160 mm. ran away useless (if it was not worse than useless through damaging the soil by erosion, etc.). But if on the contrary only 80 mm. fall in 16 gentle showers of 5 mm. each, then there is every chance that practically all this rain will be soaked up by the soil, so that a much smaller quantity of rain runs off (but 40% of the first mentioned) and twice as much is conserved for the soil and thus for the crop!

In practice, nevertheless, it is impossible for one to stand out in each shower and study it. For general use one must have a rapid, convenient, and practicable approximate rule. The above-mentioned suggested limit of roughly 8 mm. was for certain particular conditions, namely, a tobacco field, in March, on a certain soil type. Then substrating 8 mm. from each daily figure above 8 mm. and totalling the differences will give the approximate amount of run-off. The water relationships may be summarized as follows: The monthly rainfall (R) minus the run-off (A) is held fast by the soil and equals that lost directly by evaporation from the soil (B), the water held by the tissues plus transpiration through the plant (P) and what sinks away down into the depths as percolate (D). All this can be shortened into $R - A = B + P + D$.

For cultivated crops the point is that P should always be sufficiently large. A and B depend upon the condition of the surface of the soil. On a solid smooth soil A is large; with a friable, loosely worked up surface A is small. From black

81. See: **Observ. Second. Stations Neth. Indies, publ.** by Roy. Magn. Meteor. Obs. Batavia.
82. See: **Teysmannia, 20 (1909)**, pp. 151-166.

soil B is large, from a pale one much less.[83] A loose crumbly surface layer may decrease B, especially in times of long drought. D is above all a question of permeability of the subsoil. And while there is little which can be done to modify it, certainly percolation must not be overlooked in the calculations.

However it may be, the possibility exists that on one single spot in two different crop years in the same month the same amount of rain, say 120 mm. falls, and that during one year the crop fully profits, while during the other year, on the contrary, the crop suffers a lack of water. The conclusion is: a high value crop, which is also very sensitive to the differences in soil moisture, cannot get along with only the monthly quantities of rain stored in the soil. Hence there should be a more detailed measurement of the rainfall rates, making possible a more thorough rainfall analysis to explain the reasons for the differences. This is all the more necessary since it is by no means impossible that in this connection in the course of a long time there may be certain measures which should be taken, so that the crop will do well.

Another very important factor for the development of plants is the amount of moisture in the soil at various depths and throughout the whole period of growth of a crop. In this respect tobacco makes very different demands than Hevea. As yet we know but very little about all this. In vain we search in the literature for series of data. Hence with respect to the soil climate there is still quite a bit to do....

Weathering Processes and the Resulting Soil Types

Since there is no case of alternating water movement in the soil, because the climate never exhibits an annually recurring period of drought of long duration, there are but few different weathering processes in the region we are considering.

Crossing right through the entire region from the west-northwest toward the east-southeast, approximately through Selayang and Tebingtinggi, somewhat north of Bindjey, somewhat south of Medan--, there runs a boundary line. To the north of this line the gray and grayish soil tints indicate predominantly subaqueous weathering, while to the south the brown and red tints predominate and demonstrate the effects of subaerial weathering. And although this boundary can in this way be drawn across great distances on the map, and here and there in the field is even clearly marked by a low terrace; in other places its location is somewhat capricious. In bay-shaped curves the gray presses in far toward the south, or the condition may be reversed with smaller higher spots or little knolls of red color lying way to the north like islands lying off a coast out in a gray sea. This would seem to indicate clearly that there has been a time, geologically speaking not long ago, during which the land north from this boundary lay continuously, or at least nearly so, under water, while the land south of this line remained dry. And since at the present time the boundary lies at about 25 m. elevation, the change in elevation must have been about 20 to 25 m.

But this reasoning is not entirely correct, because we may well say that until roughly three-quarters of a century ago the whole region lay under tropical high forest; from the forest floor of which water did not flow so easily as off from cleared land. It is thus possible that only after clearing away of the forests was the farthest back or highest subaqueous strip exposed to drying, and the required rising of the land need not amount to the full 25 m.

There is still a strip of subaqueous soil, the bakoebakoe, lying along the sea. Part of it continues to be drenched in sea water, and part is more or less deeply leached and permeated with fresh water, so that there is fresh water above and salt water below, deeper down in the ground. If here there were a marked dry season such as the northern coast of east Java has, the salt water would work up to the surface. But here on Sumatra's East Coast, although not entirely impossible, the opportunity for this is very small.

83. Cf.: E. C. J. Mohr, Verdungstung von Wasser- und Bodenoberflächen, Bull. Dépt. Agr. Ind. Néerl. XXIX (1909).

So long as the surface of the soil does not lie more than a couple of meters above sea level then whatever salt water may be deep in the soil is of no consequence in so far as the roots of the vegetation are concerned.

But now let us first consider the condition as it was about three-quarters of a century ago, before the land was cleared. Then let us consider the conditions which have come about in the course of agricultural devėlopment:

To the south of the repeatedly mentioned boundary line, the oldest, the liparitic deposits had been subjected by a surplus of rain to continuous leaching, or at least to an occasionally suspended leaching. The resulting soils had reached the first stage of a lixivium. Higher up, for example in Simeloengoen above 600 m. the soil was a yellow lixivium with a humous surface soil, thicker and richer in humus as the site under the tropical high forest was elevated above the sea. In lower, thus warmer, localities obviously less humus remained to accumulate and the color ran more toward a brownish red and red. On the somewhat younger, dacitic deposits the color was deeper brown and brownish red, and with increasing elevation both on the soil and on the liparite there was an increasingly humous surface soil covered by a thinner humus layer.

On the very youngest lahars of dacitic-andesitic nature there was the still very juvenile, so-called "black dust soil."[84] Why these youngest deposits have become quite black and not brown or red is a soil-science puzzle of Sumatra's East Coast, which although it has already attracted much attention, still remains unsolved.

A similar soil, black dust on a pale yellow subsoil, occurs along the highway between Salatiga and Tengaran in Central Java upon a lahar which presumably came from the Merbaboe. The origin of that soil is also obscure. With the entire uncertainty as to the origin of these black dust soils it does not seem out of place to mention the following hypothesis which, it must be admitted, is still inadequately established.

Not only the liparitic, but even the dacitic eruptions and related lahars are preglacial and the lahars carrying the black dust soil may have flowed down during the Ice Age or even just before it. In the Ice age the entire Soenda platform was dry[85] as well as the greater part of the Malacca strait, in which today no greater depth has been measured than about 40 to 50 m. During that time the climate of this region must certainly have been significantly drier than now, because of the then extensive region of low land, for a great part surrounded by mountains, where now there is sea. If we also take into consideration the fact that the coastal region of Sumatra's East Coast even at present at many points of observation[86] still has less than 2 m. rainfall, then during this general increase of the dry land area, the total rainfall must indeed have been below 1 1/2 m. or even still lower, especially in Sumatra's East Coast in the narrower sense. Certainly the mountains to the northeast (Malaya) and southwest (Barisan) must have interrupted most of the rain coming from both these directions. The southeast wind had to traverse an enormously extended, flat, dry, hinterland, and since the winds from the north came from cooler regions, at the higher temperatures of this low latitude the winds were also relatively dry. In short--there were no rains coming in directly from the sea and the winds which descended from the mountains must have been less moist than is today the case. Under those conditions it is not at all surprising, but on the contrary very likely that on a lahar of fresh ejecta, deposited during this time in this relatively dry plain, contrary to the present conditions, the weathering would not have progressed as continuous or intermittent leaching. That is, the water movement in the soil was not continuous or with interrupted intervals downward but that it took on[87] a more alternating character.

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84. Regarding the exact location of these deposits (lahar tracts) one should consult the map of Druif, Meded. Deliproefst. No. 75, (1933).

85. See: G. A. F. Molengraaff, De Geologie der Zeeën v. N. O. I., in: de Zeeën v. N. O. I, (Leiden, 1921), p. 274-275.

86. For example, the series: Kloempang--Mabar--Saentis--Batang Kwis--Deli Moeda--Soengai Bamban--Laboen Roekoe Tangjong Balei with rainfall averages between 1,928 and 1,695 mm.

87. See p. 162.

In other words this water movement must have been alternating in direction, for a time downwards and then upwards. At times there must have been strong concentrations of alkali in the surface soil, in consequence of which the organic matter of the dried (grass?) vegetation was strongly carbonized. Where tropical high forest had once had a chance to develop, for example on the liparitic and on the (older) dacites reddish brown lixivium had formed, a weathering process which could not be undone. At most through repeated severe drying the color could become superficially more red. But there was no occasion for the forest, in this case monsoon forest, to disappear. On the new lahar, however, forest could not have developed before the commencement of the dry period during the Ice Age.

The kernel of this hypothesis as to the origin of the black dust soil is thus: the fresh lahar material was deposited just in the Ice Age, which signifies for this region an especially dry time for the tropics. Lahars which flowed out before the Ice Age on Sumatra's East Coast had developed a normal brown and red lixivium. Likewise lahars occurring after the Ice Age must also have developed normal lixivium, but no more of these have moved down toward the east coast. In agreement with this hypothesis it is also true that these black dust soils have never been observed on the outer or sea-facing sides, i.e. on the west and the southern sides of the Soenda plain, neither on Sumatra nor upon Java, for facing the sea the effects of the sea were always felt, thus there never could be a drought. The above already mentioned black dust soil of Salatiga, Java, lies in a place which is cut off from the sea to the south by mountains and open toward the north, toward the Java sea, which at that time was a plain, and which I believe was a dry steppe, particularly to the north of Central Java and West Java. But more about this when we consider Java.

Meanwhile, as a consequence this hypothesis contains the implication that during the dry Ice Age the leaching of the soil was unimportant and that subsequently, when as a consequence of the submergence of the Soenda plain, more rain began to fall, the soil, now supplied with adequate soil moisture, became fertile and the miserable vegetation of grasses was replaced by luxuriant tropical high forest.[88]

* * * ***

Following Druif, in recapitulation we find there are six principal residual, subaerial soil types:

1. The soil on the Tertiary formations,--especially in the west of the region we are here considering, west from the Wampoe river and also some unimportant spots in upper Benkioen, Upper Goenoeng Rinteh, and their environs. Profiles are frequently variegated in color, with much brownish red, light yellow, and in the lower parts which are transitions toward amphibian and subaqueous weathering conditions, there are dirty white portions. As a rule the surface soil is somewhat darker, though it is but seldom distinctly humous. Sometimes the soil is richer in clay or is loamy, while in other places it also has a large proportion of fine sand. Weatherable minerals are lacking, as a consequence the fertility of this type is indeed quite low.

2. The soil on the liparitic tuffs, --occurring west from the Wampoe River, to the south from type (1) and especially east from the Bloemei river as far as into Kwaloe. In the lowland the sandy lixivium is more on the bright red side; higher up, at around 500 m. and higher, it is rather more a brown and brownish yellow. Among the large crystals water-clear quartz predominates, but there is also milky weather

88. From an entirely different point of departure and via a different argument namely a geomorphological one, Volz (Nord-Sumatra, II, Die Gajoländer, p. 284-293) likewise comes to the conclusion that for a long time North Sumatra must have had a dry climate,--at least something similar to what Northeaster Java or some of the Smaller Soenda Islands now exhibit. As to time, he places this dry period in th Upper Pliocene; following the "Dry Period" he supposes that a "rain period" with excessive rains fol lowed. Though this last supposition does not appear to be necessary; there is however no real confl between my hypothesis and that of Volz.

dull sanidine with a glass-clear plagioclase which, since it is so poor in calcium, remains practically unweathered. Of the darker minerals biotite predominates, often more or less bleached. Hornblende, hypersthene and concretionary iron ores also occur, but with the naked eye one does not see much of these minerals in the soil; only the red color indicates they had been present in the original tuff. On convex terrain the subaerial liparitic soil is very pervious for water and thus also for air. Therefore on the soil type at elevations not far above sea level, even under tropical high forest the surface is but very thin and poor in humus (see Fig. 179). The higher the elevation, however, naturally the more the humus residue increases, both in the amount of the humus and in the thickness of the surface soil. Thus it is that this sandy soil type is subject to very serious erosion. Not only sheet erosion which takes with it the finer fractions (the weathered pumice stone fragments) and leaves lying on the surface a layer of crystals, so that after a heavy shower the soil appears as if sugar had been scattered over it (see Fig. 185, page 482). But this soil is also subject to gully erosion, which cuts deep, canyon-like ravines. As one will understand, surface erosion is also a factor which tends to hold the humus content of the surface soil at a relatively low figure.

3. The soil on the dacitic-liparitic tuffs,--occuring on Namoe Oekoer West, Lau Boentoe, Tamboenan, Bekioen as well as on a few other leases. The parent material of this soil contains somewhat less quartz, more magnetic iron ore, less mica and more hornblende and hypersthene than the liparitic tuff. Analyses are not yet available but the glass is presumably somewhat richer in iron, so that with the weathering of the hornblende and the hypersthene, the brownish red lixivium is darker red in color and because of a large amount of the very finest iron oxides, it has a somewhat violet red tint. The plagioclase is also richer and so is weathered sooner. The result is a characteristic, mellow, red lixivium, of quite good water-holding capacity, and but moderately sandy.

4. The soil on the dacitic tuffs,--differing in nature depending upon whether the soil lies on the so-called older phase or upon the younger. Speaking in general terms, the older phase lies between the Soengei Bingei and Soengei Petani (Deli river), while the younger tuff occurs in long strips running north and south along the Begoemit, over Namoe Oekoer West and then again east from the older phase on the Deli Toewa, Patoembah and a number of other estates.[89] To the eye there is indeed very little difference between the two brownish red lixivia, lying on the two tuffs which mineralogically are quite distinct. The practical man calls both of them "red land." But the tobacco plant quickly indicates a marked difference between them. On the younger dacitic tuff it produces a leaf which is distinctly more valuable than that grown on the older material. Why?--This is now just the question which must be examined more closely through systematic physical, chemical and biological research.

5. The soil on the youngest lahars, which are andesitic with a small content of quartz, and which Druif therefore called andesito-dacite. This type is the so-called black dust soil, lying upon a pale yellowish gray subsoil, as yet very juvenile. The most distinctive characteristic of the black surface horizon of this soil type is that in the dry condition it exhibits but slight coherence and is strongly blown about by the wind. Although also quite loose, the red soil types have more coherence, and the one mentioned under type 3 is even clearly plastic and sticky. Provisionally I can give no better explanation for this than that the black dust soil is so young that it contains an unusually large proportion of fine ash still in the form of fine sand and silt because weathering has not yet proceeded to clay. The mineralogical composition of the unweathered portion is different from that of types 2 to 4. Quartz is unimportant, and sanidine is out. On the contrary the plagioclase is much more basic being richer in calcium. Also there is much more hypersthene, as well as augite in the sand. But the most characteristic feature of the black dust soil is its high content of "humus"[90] which amounts

89. Here again the reader should consult the already repeatedly-referred-to map by Druif.

90. C. H. Oostingh, Voorl. overz. gronden tab. geb. Deli, Meded. Deli proefst. LIV (1938), p. 29.

Photo by L. Ph. de Bussy

Fig. 179. Edge of the tropical high forest, in Siantar, showing three stories: (a) the middle forest, 30 to 40 m. high; (b) the undergrowth, with many climbing plants, among which are various sorts of rattan; (c) the high forest trees, the crowns of which begin at 40-50 meters and reach up as high as 70 m. In the center two Koompassia trees--The sandy soil is relatively poor in humus.

to between 13 and 17%. But, in contrast with the humus in red soils, for example that, on the old and the younger dacitic tuffs (see (3) and (4) above), the nature of this humus is still far from being explained.

* * * * *

Having now concluded our description of the residual soil types, it is desirable to preface the discussion of the soil types deposited from water, the allochthonous soils, with the general remark that even taking into consideration what has already been said about them on pages 446-467, it will not do to draw a boundary running east and west on the map to the south of which would be only residual soil types, while to the north of it there would be only allochthonous forms.

Along the rivers in the southern region there are a number of strips running approximately south to north, the so-called pamas and the earlier pamas now called terraces, which are to be considered with the allochthonous soil formation as true river deposits. The younger they are, the more clearly can we recognize them as such. And obviously the longer they lie, while the river which had once deposited them cuts itself in deeper and deeper so that it can no longer reach them again, the more the deposits take on an autochthonous soil form developed from the allochthonous material, and so is it indeed at times difficult to decide how the soil at a certain point should be named. That is whether it is allochthonous, thus secondary, or autochthonous and hence residual. Either a long description is necessary or a formula according to the principles developed in Part I of this book should be used. For example at Selajang where the Soengei Bingei empties into the Soengei Wampoe we find that Druif calls them "low terrace mixed soils." These may be described as liparitic sand, in part already subaerially weathered in the higher hilly land plus andesitic or dacitic, in part coarse lahar material, likewise already to a certain degree subaerially weathered in the higher mountain and hilly land. These two components, after erosion and mixing together in the river, have been deposited with sand and gravel in the low land as pama and have then commenced to weather under amphibian conditions.[91] After the preliminary work by others[92] Druif could collect so much data about these soils[93] that we now have

91. All this may be condensed into the Formula: [(V.A.I--Wa.NN.ae.2)+(V.b.2--Wa.NN.ae.2)] col--H.NN.am.I.
92. See among others: F. C. Van Heurn, Jhr., Stud. betr. bodem Sum. O. kust. enz., (Amsterdam, 1923); which contains also an extensive bibliography. C. H. Oostingh, l. c. (1928), p. 12 ff.
93. H. J. Druif, Meded. Deliproefst. LXXV (1932).

a distinctly better understanding of the soils of Sumatra's East Coast than of those of any other part of the Netherlands Indies. This does not, however, deny the fact that there are many questions still remaining to be answered.

In the northern region, which has been built up principally of more or less recent river deposits, tongues of somewhat higher land run out from the hilly land lying behind. Sometimes transverse erosion valleys have cut these tongues off entirely from the hilly land, so that they form little ridges or knolls of which I have seen such excellent examples on the Tandjong Kassau Estate. The difference in color between the gray plain, which is essentially allochthonous, and the knolls weathered to red lixivium is especially striking.

Druif, in his already repeatedly referred-to publication of 1932, had provisionally designated the entire region of the allochthonous deposits with only one color. Three years later he was so kind as to send to me copies of his working sheet of his then still unpublished "agrogeological reconnaissance map," 1:200,000. For this I wish to have the pleasure of publicly expressing a word of thanks, particularly because he has differentiated the allochthonous deposits so that we can consider them in this discussion.

From this map[94] it is evident how the lahar differentiation of the higher land, in general scarcely modified, is extended out into the lowland. For that matter, it would be difficult to expect anything else. It would be different only if the lowland had been formed not as river deposits but as marine deposits, when with considerable currents along the coast the various materials would have been mixed together to a uniform whole, and ultimately much more uniform deposits would have resulted. But as it is, each river has worked independently, so that Druif could differentiate the stream deposits one after the other from east to west. Liparitic material occurs along the coast from Asahan, Batoe Barah and Serdang. Deposits from dacitic material are found in the lowland of Deli, and similar deposits in the lowest land of Langkat. But in contrast to that, and at a more southerly location stream deposits from the same material as that from which the black dust soil of Upper Langkat and Southwestern Deli had been formed, occur. Along the Wampoe river Druif draws a broad strip of "mixed soils." Likewise just east of the Deli-Serdang boundary are shown "mixed soils" along the Bloemei.--Higher up, west from the Wampoe are almost exclusively Tertiary materials. In the lowland there is eroded-off soil material from this upland and at the same time mixed with more or less volcanic material of different nature (liparitic, dacitic and andesitic) carried out by the Wampoe, and therefore of very varied composition. First beyond Pangkalan Brandan there is found alluvium coming exclusively from Tertiary rocks. Meanwhile it is difficult to imagine how in the field at first glance the origin of all these river deposits can be differentiated; they resemble each other far too much for this. But in each lahar deposit there are certain observable differentiations as to grain size: gravel banks, sandy stream banks, light, fine sandy loams, and also some finer forms, richer in clay. Now the coarser these materials are, naturally the more easily and more quickly can one observe even upon close inspection with the naked eye or with the hand lens something of the parent rocks, especially in the larger crystals, gravel, and stones.

At higher elevations the color of these alluvia is more brownish gray. Lower, and nearer to the sea, grayish; that is to say, this latter was the case during the time that the land was still covered by heavy tropical high forest. But the high forest was felled, and 30 to 40 years later it could have been seen that on the so-called lower plantations, without doubt because of oxidation of the iron present in the soil, the color of the surface soil had changed from a predominatingly gray more toward a brownish gray. That this could happen is to be ascribed in part to better drainage, but especially to the disappearance of the thick tropical high forest, as a consequence of which the rain water is now much more rapidly carried off and the air can more easily pass into the soil. In former times, when the entire region was still covered

94. Redrawn and reproduced on a smaller scale as Fig. 180, facing p. 472.

with high forest, after a heavy rainfall the water layer covering the entire forest floor gradually moved slowly from south toward north and very gradually into the rivers and so finally passed into the sea. But since then the high forest region has been converted into an agricultural one.

The most recent sketch map by Druif also shows a particular feature which should not remain unmentioned. In the center of the "fluviatile deposits of liparitic material," lying around Loeboe Pakam in the west and in Asahan in the east, north from Tebingtinggi, to Soengei Rampah Druif indicates a region, which he calls "Fluviatile deposits of liparitic, plus other volcanic material" principally between the Soengei Beloetoe and the Soengei Padang. But if on the map we follow up these rivers to their headwaters then no other parent material than liparite is evident. As to whence that "other" has come is not evident from the map. This raises a doubt as to whether all the peaks to the east of the principal series of volcanoes, which end approximately with the Dolok Tenaroh and the Dolok Songsong are entirely liparitic. This is particularly true of the Dolok Batopoe, the D. Sirapagoes, the D. Simarsompah, the D. Penoembaran and more especially of the D. Simbolon and the D. Simarito. During a trip through this highland many years ago, I gained the impression that basic rocks did occur there. The map of Druif however does not indicate any such material. If later this impression is confirmed, then this would also perhaps be the explanation why the above-mentioned region is different from the plain lying to the left and right of it.

Evalutaion and Utilization of the Soils

It is indeed a very special place which the agricultural region of Sumatra's East Coast occupies in the Netherlands Indies. In no other region is it true that by far the greater portion of the arable soil is occupied by European plantation crops as is the case here. And nowhere else do the native crops play such an unimportant role.

Before the European plantation crops, beginning with tobacco in 1863, had established themselves on the East Coast, there was still only a very scant population. Aside from a few Malay fishermen and traders the native Bataks existed by raising some crops in kaiñgins. This kaiñgin agriculture was so unimportant that before the European entered the scene the land was almost entirely covered with tropical high forest. There were no striking nor marked differences between this and the other parts of the east coast of Sumatra nor of the coast of the other islands, and there was hardly any thought of particular evaluation or utilization of the soil.

Actually, besides something obvious there is also something strange about it. A somewhat analogous case was pointed out on a part of Halmahera (pages 312-313 of this book) where, in spite of natural conditions which appear distinctly favorable, up to the present time neither an intensive agriculture nor a dense population has developed. A few possible reasons for this were sought for and have already been stated. Whether something similar for the land of Deli should be possible is another matter. However it may be, it cannot be denied that there was a distinct coincidence in that the tobacco culture commenced on land close to the present day Medan, which even today is considered to include the best tobacco soils. These soils are allochthonous, formed especially from older and younger dacitic material, described above under (4) (see pages 469, 471), so that the very first planting was clearly an economic success. This was the reason that there followed a general "opening" of the land from that first central point. From there the development has spread out in all directions over the country.

It had been discovered that this land was superior to any other in the world for producing wrapper tobacco and that a natural monopoly was the reason for and the beginning of the phenomenal development of Sumatra's East Coast as an agricultural region, which now is so well known In answer to the question: How is that possible and is the soil of Deli then so distinctive that an equally suitable soil will never be found anywhere else in the world? A brief answer would run something as follows: the soil is very certainly an important factor in that monopoly, indeed

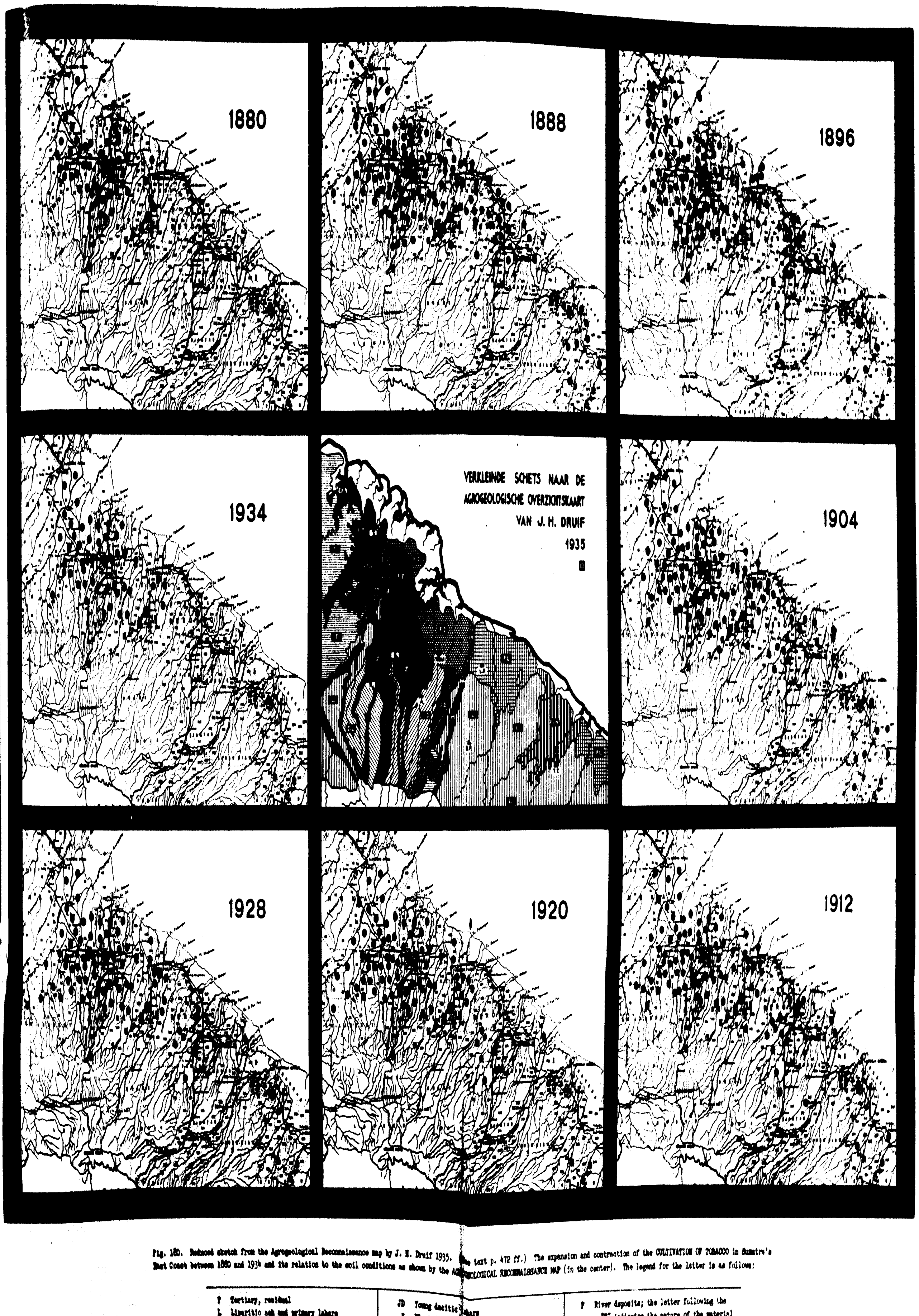

Fig. 180. Reduced sketch from the Agrogeological Reconnaissance map by J. H. Druif 1935. (See text p. 472 ff.) The expansion and contraction of the CULTIVATION OF TOBACCO in Sumatra's East Coast between 1880 and 1934 and its relation to the soil conditions as shown by the AGROGEOLOGICAL RECONNAISSANCE MAP (in the center). The legend for the latter is as follows:

T Tertiary, residual	JD Young dacitic lahars	F River deposits; the letter following the "F" indicates the nature of the material which had been carried by the streams
L Liparitic ash and primary lahars	Z Black dust soil on dacitic-andesitic lahars	V Volcanic material in general
DL Dacitic-liparitic lahars	M Mixed soils along the rivers; overwash	
OD Old dacitic lahars		

certainly the most important. But besides this more factors are favorably operating here together. They are, namely the climate with its nicely distributed rainfall and that relative humidity of the air so favorable for this crop. A good supply of capable Oriental labor suited to this fine culture, and Occidental supervision expressed in technical knowledge and the ability to organize, are other important factors. If any one of these four factors were lacking the result would certainly be disappointing. While on Java, for example, the two last-mentioned factors are also present, but such a soil and such a climate are lacking. And when in Deli the weather is not normal, it does not contribute its share, as for example when the season is too dry or too wet, the crop is of distinctly less value.

That the soil is indeed the principal factor of the four just mentioned is clear if one considers the results of the different plantations during a period of years, as these were statistically collected by Jochems and Ten Cate[95] in connection with the soil type on which they were located. Tobacco, especially the Deli wrapper tobacco, is a quality product; according to the quality it brings either a high price or only a low one. Now the best producing plantations all lie on the "black dust soil" or on the "younger dacite lahars," while for Deli wrapper leaf the liparitic soils appear less and less able to pay a profit. History gives an undisputable verdict regarding this.

In the accompanying collection of small maps (Fig. 180) of the respective years we can see on which concessions tobacco was planted.[96] It is evident from these, how in the beginning, to approximately the end of the eighties, the cultivation was rapidly extended. Indeed the rate and direction of the expansion was in proportion to the ease with which concessions could be obtained and the ease of communication. But this expansion was in no way directly related to the particular nature of the soil, which at that time was quite rightly considered to be good everywhere. That is to be explained by the fact that practically all of the land was still covered by virgin tropical high forest, and for some time after the forest was cut down the beneficial influence of the forest humus continued to greatly predominate over the influence of the variable geological and related mineralogical, physical, chemical, and biological characteristics of the soil itself. In spite of the fallows of long duration and reforestation endeavors instituted from the beginning to preserve the original soil condition as much as possible, and to regain it where the original excellent condition had been lost, the degeneration of the tropical high forest soil could not be indefinitely postponed. Consequently, in proportion to the rate and degree of decline, the more the above-mentioned influences of the deeper soil came more and more into the foreground. With the disappearance of the tropical high forest humus, which was able to mask and in a sense to make good so many characteristics and deficiencies of the different soil types the true nature of the soil without its forest humus came to light. Then a number of plantations had to be abandoned because for the cultivation of tobacco their soil[97] fell short of the mark.

Thus the contraction of the cultivated area took place along different lines

95. S. C. J. Jochems and C. H. Ten Cate, Geschied, Deli-tab. Cult., getoetst a/d. huid. kennis v/d bodem v. S. O. K., Ind. Merc. 55, 561 (7 Sept. 1932), with tables for the years 1893-1930.

96. The data for these maps were obtained from:
1. P. J. Veth, Het landschap Deli op.Sum., T. Aardr. Gen. II (1876), p. 152, with map.
2. De Regeeringsalmanakken v. Ned. Indië 1876-1888, in which is found the: "Staat van partic. landb. ondernem. op Sum. O. Kust."
3. The published notices in the Indische Mercuur 1880-1893.
4. The auction statistics of Dentz and Van Der Breggen: 1896-1935.
5. Jochems and Ten Cate, Geschied. v. d. Deli-tab. cult., getoest a/d huid. kennis v/d bodem v. S. O. K., Ind. Merc. 55, (7 Sept., 1932), 561, with tables for 1893-1930 inclusive.
6. The sketch map by J. H. Druif (1935) already mentioned on page 471.

97. The climate however also exercised an important influence for at times there were either droughts or too much rain.

than the earlier expansion. The primary reasons were thus pedological and climatological and not in the first place a question of economics. For this reason the later the date of the bordering charts showing the distribution of the tobacco culture, the better they coincide with the central soil map by Druif. The number of tobacco plantations which in the undermentioned years had plantings of tobacco, are approximately[98] as follows:

Table 97

Year	Number of plantations planting tobacco	Remarks
1864	1	Beginning
1872	about 22	Rapid extension
1880	49	
1888	148	
1896	120	1890: crisis
1904	114	Gradual decrease; conversion of
1912	97	plantations in upper Serdang,
1920	82	Asahan, and the entire coastal
1928	72	region.
1934	47	1930-1933 great crisis. Suspen-
1936	45	sion of upper plantations in Langkat and Deli.

In this way the area again contracted to its present day concentration onto the andesitic and dacitic lahars and especially onto the lowland alluvial deposits related to these lahars. Now if we compare Druif's map with one on which the plantations are grouped according to the average price of the product, as indicated by colors,[99] then we would be struck by the agreement between the two. And in this the most significant thing is not the relation between the quality (the value) of the tobacco and the soil which is there now, but the connection between the value of the tobacco and the parent rock! But this does not at all explain why this is so. No more so than the relation already pointed out on page 460, between the quality of the wine of the famous wine districts (the district around Bordeaux, the Bourgogne region and the wine districts along the Rhine) and the particular features of the soil of those very restricted localities where the finest of the fine wines are made. For the time being we must admit that the tobacco plants in Deli and the grape vines in Europe obviously react qualitatively to certain soil differences to a degree which we men with all our elaborate methods of research have still not been able to approach. So little do we yet know about these soil differences that we cannot choose between the two following statements: the good lands have something essential, which the bad ones lack; and the poor lands have something essentially deleterious which is absent in the good ones. Now to find that "something" --be it good, or be it bad--brings us to the problem which will make the preparatory work of Druif of merited significance.

In another respect also, Deli tobacco cultivation is different from that of all other crops in the world, namely, in the very long fallow. This is possible because Deli tobacco is such a high value crop, in a good year bringing in more than US $1,200. per hectare. More than that: if the crop is not to be a failure there must be a long fallow, for only with the proper soil condition which approaches as much as possible that of fresh forest soil, is the desired high value product obtained. It is because of this that after one year of cultivation the soil is allowed to lie under forest growth for at least 5 to 6 years, but preferably 8 to 10 years, a treatment which brings the soil back again into this necessary condition. It is indeed true that the humus in the soil which is lost during the one year of cultivation must be replaced. However if by humus is meant merely the loss on ignition as determined in the chemical laboratory for example, then this conception is very likely far too simple. Probably the microflora in the soil, which during the year of cultivation is without doubt strongly modified, must as far as possible be reestablished. Probably different physical characteristics such as crumb structure, permeability, water and air capacity need to be favorably altered. To completely reestablish the original tropical high-forest soil conditions must indeed remain an unobtainable

98. Because of various changes in name and dividing up and combining of plantations, no greater accuracy is to be attained; nor for our purpose is it necessary.

99. E. C J. Mohr, Ind. Merc. 56 (1933), p. 16, 227.

desideratum, from the practicable 5 to 10 year fallow a high value product may be obtained. While this may not be the highest obtainable quality tobacco of the tropical high forest soils of the previous century, it is quite good enough. But in so far as our experience and knowledge of today extends, to get a satisfactory tobacco leaf it is imperative for the soil to lie fallow under forest during a considerable number of years.

* * * * *

It is necessary to devote a few pages to a more general question, namely the humus of the tropical high forest.

If a planter once qualifies a soil as "excellent, splendid, magnificent"--the odds are ten to one that the second word will relate to the humus content: "excellent humous soil," "splendid humus-rich soils," "magnificent soil, the purest humus." Apart from the exceptions, which where necessary in this book are always scrutinized even under the magnifying glass if necessary, in general the planter is right, especially if he expresses it thus: "there is really nothing which can excell the humus soil of old tropical high forest." Where this is so, this knowledge has been obtained on an empirical basis, by experience. But the usual explanation, which is given is still not the exact one, or at any rate not the only one nor the principal one.

As has repeatedly been touched upon in this work, humus exerts a beneficial influence in three directions: physical, among others through making looser an otherwise too solid soil; by making a too loose soil more coherent and more able to hold water; and by facilitating chemical transformations so that the soil will gradually give up to the plant roots the well-known plant nutrient materials which the humus holds absorptively, and to serve biologically as food for the soil organisms, the microflora and fauna which are so important for the good growth of cultivated plants. Besides these and still other generally recognized characteristics which we need not mention here, there is however one peculiarity of this humus to which I wish at the present time to call attention.

How does the humus of the tropical high forest come into existence?--From all sorts of plant refuse, especially from the trees of the high forest. These trees grow using the carbon dioxide of the air, water from the soil, and the other substances which the roots take up from the soil--the nutrient plant materials. Now in the last few years it has become evident that the essential elements are not all comprised in that well-known set of about ten elements, but in addition there are still about 20 more, so-called minor or trace elements, which are usually also essential though in the most extremely small quantities. This has been discovered indirectly.

In the soil these elements are present in such small amounts that they have evaded the usual chemical analysis and thus for a long time had escaped attention. Of importance, particularly for these elements, we can differentiate the following concentration processes:

1. The trees, or perhaps only some of them, in their forest life of many decades and longer, concentrate these elements out of a large mass of soil, from as far as the roots can reach.

2. The waste portions of the trees fall onto the soil. Much organic matter is broken down, but these elements are concentrated in the humus which remains.

3. In the transition of the humus layers into peat, lignite, and coal, further concentration takes place.

4. Upon burning of coal a final concentration in the ash occurs.

Thus it is comprehensible that a number of minor elements were first found in the analysis of coal ash[100]; thereafter this method of research,[101] continually more refined, was also applied to coal itself, to lignite, and is now being applied to

100. See for example: V. M. Goldschmidt, Rare elements in coal ashes, Ind. and Engin. Chem. 27 (1935), p. 1100.

101. This method of study is the so-much-refined spectral analysis, with which V. M. Goldschmidt and his school have obtained such astonishing results during the last decade.

humus. This method of analysis has been but seldom used for the plants themselves and their ash, or for the soil on which they grow.[102] But the data we do have indicate clearly that some plants have an enormous power (sometimes as much as 3,000 times as great as other plants) of accumulating certain elements, while other plants seem to lack this capacity entirely. This means that the humus coming from a certain plant or plants may not by a great deal be the same as the humus from another sort of plant,--be it remembered we are here referring only to the minor elements. In a certain sense forest humus is an average product,. something from many sorts of plants. But how then has the tropical high forest humus come to possess the minor elements in larger concentration than the humus-free and vegetation-free ground? These elements have already passed through some plant body or another and probably have not been unwelcome in them. Perhaps they were essential, even though only in traces, for these particular plants to fully develop. If that be actually the case, then new generations of these plants or other plants, which have similar requirements, find in the forest humus a savings box of such necessary little things, and this should be quite sufficient to explain why if one be determined to grow special crops which have particular needs for these minor elements, "really nothing excells old tropical high forest humus."

The perspectives which these new discoveries and the related physiological considerations open up are of vast extent. By way of example, a few observations will be made with respect to Deli tobacco. Just as for each crop plant, also for tobacco one must study which minor elements are of significance. We have already learned that without boron there is no development of tobacco. The soil and/or the fertilizer must thus possess at least a minimum of that element. Further we may accept as probable that besides a minimum for each minor element, which the plant must have or it suffers, there also exists a maximum, above which that element acts as a poison to the plant. And between the maximum and minimum lies an optimum at which the plant, all other conditions remaining the same, grows the best.[103] This likewise applies to the elements already long-known as essential constituents of plants. Thus the minor elements operate similarly to the common ones, the difference being only one of degree.

Now the conclusions: In the soil without humus a given element occurs at a concentration far below the minimum for tobacco. Hence this plant cannot grow well. But in the humus of a tropical high forest on this soil that element, for example, may have been concentrated to 25 times the quantity so that it is now present in a quantity well above the minimum required. Thus tobacco grows excellently. Suppose now that the plantation lies on land with a considerable slope so that the humous surface soil is eroded completely, then no amount of fertilizing with pure N, P, and K alone can help. Tobacco cannot grow properly on this eroded soil. Nor can a green manuring make good again that deficiency in one year, nor even in eight. We may accept it to be true that the high forest has brought from great depths and over a very long time the minor elements to the surface and accumulated them in its humus. Consequently this new reason is another one to be added to those already long-known reasons for the exercise of the greatest of economy in the conservation of all of the high forest humus.

If each of two plantations lies upon a different lahar (mud flow) and they produce different tobaccos, then it is possible that the land on the one lahar possesses certain minor elements in optimum concentration and that the land on the other has either less than the minimum or more than the maximum concentration. Only accurate analysis can determine this with certainty. The question can become still more complicated if one or more of these elements plays a role in the life of bacteria or fungi, which as parasites cause definite diseases of the tobacco or if, on the other hand the minor elements increases the resistance

102. For example: Horace G. Byers, Selenium occurrence in certain soils, etc., U. S. Dept. Agr., Wash., D. C., Techn. Bulletin No. 482.

103. Cf.: V. C. van Gennep, Diss. Utrecht, April '36, with an extensive list of references to the literature.

Photo by J. Brouerius van Nidek

Fig. 181. Young planting of tobacco on Sumatra's East Coast, on liparitic terrain, very much inclined to erode. For the greater part the humous surface soil has already disappeared. Very little opportunity for regular layout in planting.

against diseases, rather than predispose the plants to disease. In short--if different quality tobaccos markedly different in value grow on different (lahar) soil types there is indeed an incentive to include the minor elements in an extremely detailed study of these soil types. Without such research fertilizer experiments along the old empirical lines will always remain defective and, as the past has taught over and over again will give results from which no reliable conclusions can be drawn.

For something indicating the direction in which to search for the minor elements, one should be able to draw upon Druif's research,[104] in which it appeared that liparitic tuff always possesses orthite, which contains the minor elements cerium, lanthanium, yttrium and perhaps still others. While orthite was practically absent from the products of the other eruptions; titanium minerals are never or almost never found in liparite.

Perhaps these differences are of very small significance, and other differences are of much greater importance. Only research can decide this. But even as long ago as the commencement of this century the use of ash of especially successful tobacco plants as a fertilizer gave excellent results in the new plantings. In this there was already an indication that the motive for the fertilizing "was to give the young plants in a concentrated form what the previous generation had collected perhaps with difficulty out of the soil." While there was perhaps a real basis for this, yet in this practice there was absolutely no indication as to which elements in the ash were essential and which ones were not.

Turning back to the series of small maps, we see how the tobacco culture has been gradually contracted from its greatest extension in 1888 onto the young dacitic and andesitic lahars, the liparitic area

104. J. H. Druif, Bull. Deliproefst. No. 32 (1934), Table X, preceding p. 65.

Photo by J. Brouerius van Nidek

Fig. 182. Young planting of Deli tobacco on heavily eroded terrain. In spite of the terracing the humous surface soil cannot be retained.

having been more and more abandoned. We might say that this was proportional to the decrease in the humus content of the tropical high forest soil. But besides that, however, the forest humus disappears more rapidly from the upper than from the lower plantations; (one need merely compare Figs. 181, 182). Thus if even on the dacitic lahars plantations must be given up, the first ones will be the eroded upper plantations. And this is actually the way it is happening.

In time there will recur a desire to open up these abandoned plantations. How soon can this be done? Only some experiments, around the 5th to the 10th year, will give the answer. From the above considerations relating to the nature of the forest humus, however, it follows that we must take into consideration the possibility that for the production of high value tobacco on some lands, a very long fallow, for 25 to 50 years at least, is necessary. Perhaps from this time on there will be definite dependence upon regular reforestation. In any case the soil map of the Deli experiment station should be taken into consideration.

* * * * *

More or less closely related to the abandonment of the unprofitable cultivation of tobacco on a number of estates, we see the beginning of new crops which promise more. Considering past events it is certain that at least most of the new undertakings will be established on liparitic soil without taking greater risks on other soil.

It was at the close of the last century that coffee culture, particularly the cultivation of Liberia coffee was started in Upper Serdang. It had a strikingly comet-like existence: coming up rapidly and splendidly, while not even 20 years

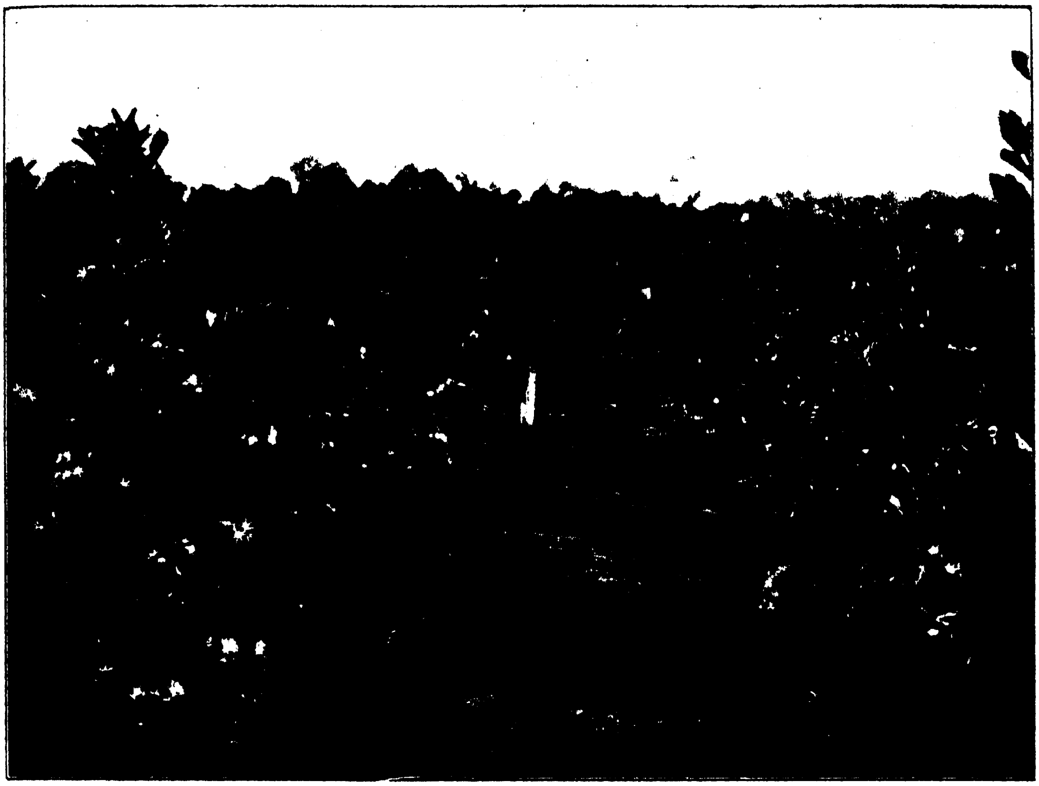

Photo by Kleingrothe

Fig. 183. A quite flat portion of a Liberia coffee plantation on liparitic tuff in Upper Serdang. The dark surface soil is still preserved, but the plantation is also young.

later it had faded away. In the first years this crop stood out prominently, but then came the adversities of which the fall in price of the produce was certainly the foremost. Yet there were also diseases attacking the bushes as well as a serious plague of caterpillars. Moreover fatal erosion developed, and this completely stripped off the humus layer (see Figs. 183 and 184). At the time it was contended that the gardens should always be maintained under clean cultivation which according to the experience of the previous 40 years was believed to be the best method of culture. But later other considerations were found to have more force. It is not to be wondered at that when the less risky rubber cultivation arose, that, in general, the planters quite rapidly gave up the cultivation of Liberia coffee, replacing it by rubber, just as at an earlier time Liberia coffee had replaced other crops.

Between 1910 and 1920 there was a revival of coffee planting, but this time it was *Coffea robusta*, used especially as a catch crop between the rubber trees. When the rubber trees matured this coffee was of course destined to disappear.

Of the 40 estates, which in 1900 had plantings of coffee, on 15 of them in 1910 the Liberia coffee was out; but 15 new ones had come in. In 1920 on 28 of them the rest of the Liberia coffee had been cleared out. On the other hand 51 other estates had new *robusta* plantings. Thus in 1920 a total of 63 plantations had coffee. Between 1920 and 1930 from fifty of these estates the plantings disappeared, while 5 new ones came in. But after 1930 the coffee disappeared almost entirely, for in 1936 not a single

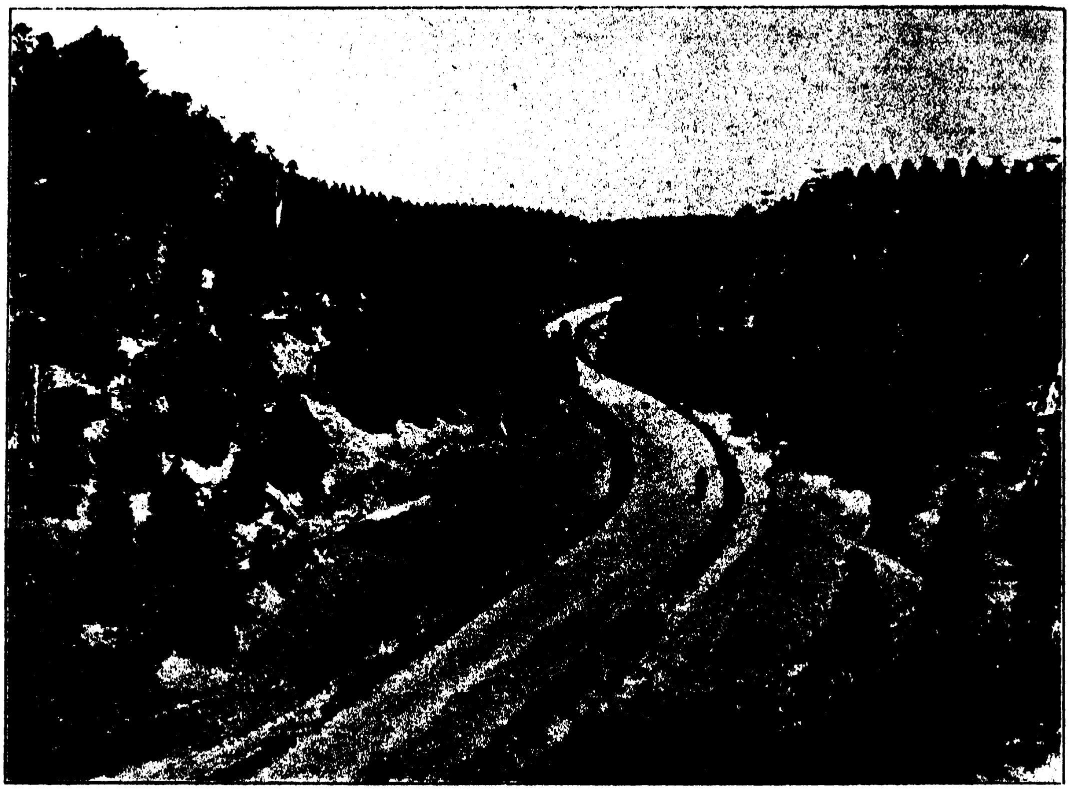

Photo by Kleingrothe

Fig. 184. Liberia coffee plantation on liparitic tuff in Upper Serdang. The humous surface soil has already disappeared. The white sand easily washes off (note the heap beside the road!). The stand of the coffee trees is still excellent, but a few years later they will have disappeared.

producing plantation is reported.[105] Only one plantation maintained its Liberia plantation more than 30 years. Within one-third of a century both the beginning and the end of coffee culture on the East Coast occurred. If Liberia and robusta are separated, then neither of the two kinds lasted more than 20 years.

* * * * *

A godsend for the declining bankrupt tobacco and coffee plantations was the rise of rubber cultivation. This first commenced with Ficus, but very soon thereafter followed the planting of the much more productive Hevea, which has now entirely displaced the Ficus, because among other reasons the Hevea is a relatively rapidly growing tree with extremely modest demands as to soil and climate.

With respect to rubber, it is difficult to say anything about the productivity of the soil of Sumatra's East Coast since in the quarter century, within which this culture has come into existence, there has been a continual selection of planting material, with new budded strains (clones) of greater productivity replacing the seedling trees. Now, still better clones

105. Data collected from the Handb. v. cult. en Hls. Ondern (1895-1935).

have replaced the earlier selections. These changes obscure any decline in the productive capacity of the soil, as a consequence of the cultivation of this crop. After all Hevea culture is still too new to make a decision possible, but the selection for production explains why in the cultivation of rubber the average production figure per hectare continuously rises, while that for other crops falls, sometimes heavily.

Thus for Sumatra's East Coast we find these rubber production figures:[106]

For the years:	1923,	1924,	1925,	1926,	1927,	1928,
Kilos per Ha.	340	327	357	412	403	423

1929,	1930,	1931,	1932,	1933[107]
444	426	460	443	468

A significant rise is quite apparent, and this is still continuing, with yields of 550-600 kgs. per hectare being probable in the near future. Comparing the figures for 1934, the average production on Java amounts to 414 kg./ha., while on the other islands than Java the plantations average but 363 kg./ha. But this indicates nothing about the "fertility" of the soils planted to Hevea on Java as contrasted with those of Sumatra. The influence of methods of cultivation and especially the use of high producing clones in Sumatra far outbalance soil factors. For that matter, in that same year 1934 the figures[108] for Sumatra's East Coast were 454, for Atjeh 428, and for Tapanoeli 439 kg./ha., so that the rest of the rubber regions outside of Java cannot average more than 145 kg./ha. But without additional facts, to draw any conclusions from these figures is very dangerous. Yet we may safely say that the differences between the cultivation of the plantation rubber and native rubber are important factors.

From casual inspection, the distribution of the rubber plantations over the region does not seem to have any connection with the soil type. But more than that we cannot now say.

* * * * *

A short time after commencing the cultivation of rubber, the planting of tea was begun on Sumatra's East Coast, and particularly in a definite region to the south and southwest of Siantar. While it is true that much earlier some tea had been planted in Upper Deli, the terrain there was so rough that tea never developed into a profitable crop. In Siantar the terrain being weakly rounded and sloping off gently toward the north and northeast, is much more favorable (see Fig. 185, page 482). According to the map of Druif, this region is purely liparitic. But still one cannot help wondering why almost all tea plantations lie so thick together while there are none in Raja, west from there, and only a few in Upper Tanah-Djawa and Asahan. According to the map just mentioned, the soil type in all these places is the same. But there seems some reason to doubt this. It seems perfectly reasonable to suppose for example, that from the Simbolon and the Simarito a particular influence goes out or has gone out. This influence finally reached the coast where the tobacco plantations "of the coast" held out the longest and where Druif established a divergent soil type. Since up to the present time Druif has been employed solely in researches connected with tobacco, the available data are still inadquate.

According to the studies of Boerema[109] the climate in the regions referred to is so entirely uniform that there is no use searching in this direction.

But a quarter century ago, when tea planting was begun in Siantar, it was then a step in the dark since at that time no one in the Netherlands Indies had had any experience in growing tea on liparitic soils.

106. Statistiek v. aanpl., produc. aanpl. en productie v/d gr. cult. v. Sum. O. k., Atjeh en Tap., Uitg. Hls. Ver. Medan en A. V. R. O. S.--(annually).

107. Because of the consequences of rubber restriction, it would be meaningless to record here the figures for the later years.

108. Econ. Weekbl. 15 Febr. en 12 Juli 1935.

109. J. Boerema, Regenv. N-deel Sum. O. K., Verh. Observ. Batavia No. 11 (1923).

Fig. 185. Tea estate, young planting with blind ditches to limit the erosion, in Siantar. Because the finer soil constituents have been washed into and off over the surface, leaving behind the coarse sand, the soil seems as if it were covered with sugar. (See pp. 468, 469).

Fig. 186. Siantar. A young tea planting on liparitic soil, with ipilipil (Leucaena glauca) for green manure in rows between it.

However when tea plucking commenced, the production exceeded all expectations. It is true one can pluck quite coarsely, since the quality and the state of the market permit that, but notwithstanding the coarse pluck, yet on various plantations the pluck can be repeated every 7 or 8 days for long periods while on Java the average time is 10 days between pluckings. In connection with changes in the requirements of the market, first in one region then in another there has been a gradual transition over to a finer pluck, which gives significantly less yield but higher quality. Still later (1933), as a result of restriction, the production was limited still more. Consequently when we look over the following series of figures for the average production[110] of the entire tea producing area of Sumatra's East Coast, nothing is to be deduced from them as to the productivity of the liparitic soils for tea.

Year	1923,	1924,	1925,	1926,	1927,
Kg./ha.	813	808	763	754	672

	1928,	1929,	1930,	1931,	1932
	689	672	630	670	682

As is also true in the case of the other crops, certain cultivation measures for the maintenance and particularly for the increase of the fertility of the soil are taken by every planter. In the beginning, more than 20 years ago, the clean weeding system was followed very generally for tea but even then there were endeavors by means of terraces and digging of catch pits (see Fig. 185, page 482) to guard against the loss of the humous surface soil through erosion. Later, especially after 1916, the above-mentioned system was replaced more and more by that of selective-weeding, and there came into vogue the planting of green manures (see Fig. 186, page 482) between the tea bushes. Because of root competition, not alone for plant food materials but also for soil moisture, at the present time the planters are again much less optimistic with respect to "good natured" weeds and green manures. Artificial fertilizers, originally relegated quite into the background, later came to be used more and more. But even now which of them is the best cannot be stated with certainty. Thus in the course of time first one feature and then another of plantation practice is altered.

On Sumatra's East Coast somewhat later than the tea culture, the cultivation of oil palms was commenced. If we study on the map where these plantations are located, nothing definite is to be concluded as to the soil type. Oil palms make relatively heavy demands upon the soil, but these are of a general nature, such as a loose and mellow structure, but still with satisfactorily water holding and water-supplying capacity, good aeration, and preferably a plentiful supply of plant food substances. On all convex lands, as on the red knolls, these palms do not do so well, since with but little drought they suffer from a lack of water. On heavy clay also they do but tolerably well, or even badly, due probably to lack of air and difficulty with the supply of water. On submerged subaqueous soils they languish, unless good drainage can improve the soil aeration. If however all these requirements are met, then since the climate provides an optimum of warmth, sunlight and moisture for this crop, and the liparitic soil, on which most of the oil palms are standing, also appears to be favorable, so that as a result of the exemplary cultural measures employed and proper working up of the crop the yield is high, higher than elsewhere in the world.

With the appropriate modifications we can say the same of the culture of sisal. White made a special study[111] of the soils on which sisal is planted. The noteworthy point about sisal, which in origin is a savanna plant, is that if all the other hardly modest demands of this plant are provided for, its need of humus seems to be only moderate. As the reader has already seen this is entirely different from tea. And it is also different from gambier which is raised only in one place, in Asahan.

110. Calculated from the repeatedly mentioned annual statistics of the Hls. Ver. Medan and A. V. R. O. S. by dividing the respective figures of "production" by those for the "productive plantings." This is obviously but a rough approximation.--Such statistics are not available for the years before 1923.

111. See: J. Th. White, Teysmannia, 33 (1922), pp. 567-574.

This is a crop very sensitive to and appreciative of humus. In the course of time as the humus disappears through burning by the sun and by erosion, the gambier yield also seriously declines. Just as with tobacco, the cultivation of gambier must shift about over the terrain, alternating with fallow and reforestation. But while with tobacco 8 years fallow alternates with about 1 year of cultivation, gambier can be grown for a much longer time on the same land. But "after 7 to 8 years the driving force of the gambier is so exhausted that it is no longer profitable to maintain the fields, so that unless Hevea or some other crop is planted most times young forest is allowed to come in."[112] On the contrary, for the gardens of natives of Palembang Heyne[113] records figures of 8 to 15 years productivity, with good care 10 to 12, but with bad care only 5 or 6 years. Yet the cultivation always runs out and then it must be started again on new forest land.

That with a back country of much liparitic, as well as dacitic andesitic ash it is obvious there should be a sandy coastal strip with many sandy ridges and sandy plains. Also for a long time, <u>cocos</u> have of course been planted by the natives on all of these coastal sandy soils. Later a few European coco plantations followed all lying in a strip approximately 5 to 10 km. from the coast. But few particulars regarding coconut culture here are to be found in the literature. At present there is nothing available on record regarding the productivity of the soil with respect to this crop, although doubtless very significant differences in yield could be shown, depending upon whether the sandy ridges and flats are of liparitic, dacitic, or andesitic nature.

* * * * *

If we go into the above summary of important plantation crops, involuntarily we conclude that the soil of Sumatra's East Coast must indeed be extraordinarily fertile. Yet that is only correct if the conditions are made good, if these soils receive to the full their requirements. Elsewhere in the Archipelago there are kinds of soils where a transgression in the correct handling of the soil is not so directly and not so very seriously revenged. The contrary is generally true of the soil types of Sumatra's East Coast, for the Deli soils are sensitive. This also appears to be the case when we consider <u>figures of analyses and yield</u> and compare them with similar figures for other regions.

It was in the typical tobacco growing localities that soil samples were first collected and analyzed in the laboratory. In those days there was no adequate study of the soil as a whole. In the Communications of the Deli Experiment Station 1907-1913 many such analytical figures have been published. But these figures do not lead to significant conclusions. For that matter, as long as the work was not done on a foundation such as that which Druif has provided, it could not be otherwise.

It is true that using the data, from chemical analyses by the Deli Experiment Station[114] Bongers[115] has summarized the chemical characteristics, "making up surveys relating to the fertility" that is to say studying the figures for the N content and the amounts of P, K and Ca soluble in HCl. He obtained the following averages (Table 98) and minima and maxima expressed in hundredths of percent by weight:

The "groups" of Bongers are as follows:

- A = alluvium, in more or less broad strips along the coast, formed under the influence of the sea.
- B = Marine diluvium, the whole strip between A and the 100 m. contour line.
- B_1 = B from Asahan to Serdang; (maritime liparitic tuffs).
- B_2 = B in West Langkat; (the same origin as B_1).
- B_3 = B covered by andesitic material.
- C_1 = primary liparitic tuff soils above the 100 m. contour, in Siantar.

112. B. Geiger, Die Gambirkultur auf Ostsumatra, Tropenpfl., <u>36</u> (1933), p. 69.
113. K. Heyne, De Nuttige Planten van Ned.-Indië (Buitenzorg, 1927), II, p. 1388.
114. Meded. Deliproefst. II, 175-236; IV, 155-171; V, 255-257; VI, 293-295; VII, 171-173 and 297-299 (1907-1913).
115. H. C. Bongers, Meded. Landb. Voorl. dienst (Dept. L. N. H.), No. <u>5</u> (1920).

Table 98

Soil Group	N		P_2O_5		K_2O		CaO	
	Average	Min.-Max.	Average	Min.-Max.	Average	Min.-Max.	Average	Min.-Max.
	Hundredths per cent by weight							
A	24	8-222	6	0-31	12	2-33	35	8-195
B_1	19	12- 74	2	tr- 7	20	2-37	14	5- 28.
B_2	23	11- 72	3	tr-14	11	1-33	13	1- 27
B_3	32	6-136	3	tr-18	9	tr-33	20	2- 49
C_1	15	9- 28	1	tr- 3	15	9-28	6	3- 10
C_2	26	18- 37	1	tr- 7	6	3-12	7	2- 12
D	15	3- 19	2	2- 2	11	9-13	3	2- 4

C_2 = the same, in Upper Langkat,
D = Tertiary soils, in West Langkat.

But now on the basis of the recent map by Druif, this grouping is seen to be irrational. Moreover, the locations are too vague, so that no definite conclusions can be arrived at. Even so, there are two reasons for including these figures here:

1. In order to be able to compare them with figures obtained in a similar manner elsewhere in the Netherlands Indies, even though the possible comparisons are only very general.
2. In order to let it be seen, how astonishingly divergent they are, even within related groups.

As to the mechanical analyses (granular composition) of the samples of the soils of Sumatra's East Coast, the Deli Experiment Station[116] between 1910 and 1913 carried out a respectable number (379) of determinations. Unfortunately, however, these are practically worthless, because 1st--since only the plantation (sometimes only the sender's name) is given, we do not know either the exact place of sampling, nor the soil type, nor anything about the horizon or layer from which the sample was taken, nor the thickness of the horizon. And 2nd--since the division into fractions of different grain size was not carried out far enough, and nothing is recorded about the nature of the fractions obtained. Neither the color nor the consistency characteristics, nor anything about the mineralogical composition is recorded.

In his thesis[117] Van Heurn has given the mechanical analysis of a profile sampled in a pit at Kampong Baroe, 4 km. south from Medan and already described elsewhere.[118] According to Druif's map this point falls in the "old dacitic lahar." How thick this lahar is at that place, however, is not known, though it is most probably more than the 7 m. of the profile referred to. According to the analysis given, this profile is certainly not of material deposited all at one time. For that matter Van Heurn himself differentiated many layers. It seems worth while to include these 15 analyses, with the figures rounded to whole percentages (see Table 99, page 486).

What strikes one at once in these analyses is the high percentage of medium and fine sand, between 500 and 1,000 mu for the coarser numbers, between 200 and 20 mu for the finer. If one keeps in mind that sand above 200 mu is very pervious, but only slightly water holding, while on the contrary fine sand between 200 and 20 mu is also satisfactorily pervious, although it is much better able to hold water in the pores. Then one sees with satisfaction that with perhaps the exception of the last 2 numbers all these soil layers are quite nicely water holding and those which I have called "loam"[119] are particularly so as is

116. Meded. Deliproefst. V, 327-335; VI, 296 and VII, 300.
117. F. C. Van Heurn, De gronden v/h cult. geb. v. Sum. Oostkust enz., Diss Delft (1922), p. 99.
118. F. C. Van Heurn, Meded. Alg. Proefst. A. V. R. O. S., Alg. Serie IV (1918), Fig. I.
119. The last column I have added to the table, since some of the names used by Van Heurn (Nos. 2, 7, 10, 12) are quite divergent from those usually used.

Table 99

MECHANICAL ANALYSIS OF A SOIL PROFILE AT KAMPONG BAROE, MEDAN

No.	Depth in m. Approx.	I 2-1 mm.	II 1-0.5 mm.	III 0.5-0.25 mm.	IV 0.25-0.10 mm.	V 0.10-0.05 mm.	VI 50-20 mu	VII 20-5 mu	VIII 5-2 mu	IX 2-0.5 mu	X less than 0.5 mu	Van Heurn's Names	My Suggested Texture Names
I a	1/10	2	4	20	26	17	8	7	9	4	3		Medium sandy loam
I b	1/4	1	4	25	30	15	6	5	7	4	4		" " "
2	1/2	1	4	41	40	6	2	1	2	1	2	Sandy clay	Somewhat loamy sand
3	1	0	1	15	47	16	7	4	4	2	4		loamy fine sand
4	1 1/2	0	0	3	16	33	21	9	8	5	5		very fine sandy loam
5	2	1	3	28	30	13	6	4	5	3	7	Sandy brown	Sandy loam, loamy fine
6	2 1/2	1	3	18	28	24	10	5	6	2	3	earth	sand
7	3	1	1	4	18	38	17	5	4	2	10	clay	Very fine sandy loam
8	3 1/2	0	2	15	41	25	8	3	2	1	3	sand	Loamy fine sand
9	4	3	3	24	47	17	2	1	1	1	2	sand	Somewhat loamy sand
10	4 1/2	0	0	9	40	33	12	2	1	1	1	sandy clay	Somewhat loamy fine sand
11	5	6	9	40	25	13	4	1	1	1	1	sand	Sand
12	5 1/2	0	0	7	32	41	15	2	1	1	1	sandy clay	Somewhat loamy fine sand
13	6	0	1	11	48	30	6	1	1	1	1		Fine sand
14	6 1/2	3	11	53	30	2	0	0	0	0	1	sand	Sand
15	7	5	9	48	34	3	0	0	0	0	0		Sand

true of the cultivated soil in the same "old dacite" tract. The sand of this soil consists to a great extent of plagioclases (richer both in sodium and in lime), hornblende, hypersthene, volcanic glass, iron ore, some quartz and iron ore.[120] It thus contains a considerable reserve of plant foot materials.

If we now compare the mechanical analyses of these dacitic lands with similar analyses of Siantar soils, which we may accept as having originated from liparitic ash, then a marked difference is evident. Deuss has published a large number of mechanical analyses,[121] practically all of samples from existing or prospective tea gardens, and for this reason roughly localized geographically. All these soils have the common feature that in them the fractions 100--to 50 mu and 50-20 mu, thus the very fine sands, are essentially lacking. Below is a selection from the total of about 300 analyses. It is a series in which the percentage of coarse fractions decreases as the proportion of the fine particles increases. This indicates that in the series the rapidly weathering volcanic glass gradually disappears and goes over into clay, or at least into extremely fine, colloidal material. At the same time this transformation increases the water capacity, as is evident in the liquid limit, and likewise the hygroscopicity, a value coinciding approximately with the point of color change. These same features are evident in the Atterberg consistency figures,[122] recorded at the same time (see Table 100, page 487).

In contrast with the Deli soils, there is no mention of "loam," for the fractions V (0.1-0.05 mm.) - VIII (2-5 mu.) are the very ones present in only very small quantities. As is shown by a comparison of the fractions I - III of these soils with those of the previous table, the liparitic ash begins as sand. The glassy part (pumice stone) then weathers, converting the sand into clayey sand, thereafter into sandy clay.[123] There really isn't any true clay--this soil type has too little stickness (note the always positive surplus). A better name for this soil is a brownish

120. Cf.: J. H. Druif, Bull. Deliproefst., 32 (1934), Table X.

121. J. J. B. Deuss, Theegronden v. Java en Sum., Meded. Proefst. Thee, 89, pp. 102-114.

122. Cf.: E. C. J. Mohr, Meth. Atterb. t. bep. consit. cijfers, enz., Meded. Labor Agrogeol. en Grondond., I (1915).

123. Also Deuss (l. c., p. 49) calls the Siantar soils sandy clay. White (Teysmannia, 33 (1922), pp. 567-573 calls them sandy sabulous clay soils; in comparison with what is called sandy clay in the Netherlands these of Siantar however possess much too much of the fraction less than 2 mu. But as it happens that as long as the conception "sabulous" is still today so poorly defined, the use of it in the Indies certainly cannot be recommended.

Table 100

MECHANICAL ANALYSES AND ATTERBERG CONSISTENCY VALUES OF SOME TEA SOILS

Number Deuss	Mechanical or Granular-Analysis:										Consistency Figures:									
	I 2-1 mm.	II 1-0.5 mm.	III 0.5-0.2 mm.	IV 0.2-0.1 mm.	V 0.1-0.05 mm.	VI 50-20 mu	VII 20-5 mu	VIII 5-2 mu	IX 2-1/2 mu	X less than 1/2 mu	Liquid Limit Vl	Rolling Out Limit Ur	Solid Limit B	Sticky Point Kl	Color Change Point Osp	Maximum Water Holding Capacity Vl-Osp	Workability Kl-Ur	Plasticity Vl-Ur	Surplus Kl-Vl
787 C ..	27	23	24	11	3	4	2	2	2	2	36	--	--	--	10	26	--	--	-
1161 A ..	19	23	21	8	3	2	4	7	8	5	23	--	--	29	5	18	--	--	+ 6
1741 B ..	14	19	19	10	2	2	3	7	9	15	24	20	12	28	3	21	8	4	+ 4
1743 D ..	15	16	18	9	2	2	3	5	9	21	29	17	14	34	5	24	17	12	+ 5
1163 C ..	19	17	13	5	2	3	2	4	8	27	33	22	18	34	7	26	12	11	+ 1
1729 C ..	7	9	14	9	2	3	4	6	11	35	40	30	23	45	6	34	15	10	+ 5
115 B ..	7	6	10	7	3	2	3	8	14	40	45	41	34	51	14	31	10	4	+ 6

yellow sandy lixivium.

Under the allochthonous soil types, formed from liparitic material, there naturally occur granular compositions of diverse combinations, with consequently correspondingly variable physical characteristics. Isn't it always the case that in the low lands the water deposits here a sand bank or sandy stream bank, there a loamy light soil or even heavy clay?[124] And then through reduction and leaching of the iron, the yellow to reddish brown colors of the deposits become more gray and bluish gray. But also in the higher land increased plasticity and decreased permeability can result from the clay (less than 2 mu) being washed down through the soil into the deeper horizons. In this connection Deuss says:[125] "The silt of the Siantar soils can very strongly run together and become only slightly pervious. Where the humus content is not high, this imperviousness does not decrease sufficiently. For various reasons endeavors to get tea plants to grow in the silt alone were an entire failure, one reason being the strong "running-together" of this silt. The practical man has, however, learned that the existing relation of sand to silt in the Siantar soils is favorable, so that these soils must be included with the excellent plantation soils." Meanwhile, for the perviousness as well as for the water capacity, I am inclined to consider a generous percentage of well divided humus still more important than the ratio of sand to silt.

Regarding the Atterberg consistency figures Deuss says:[126] "The figure for the maximum water capacity seldom exceeds 30 and is thus low. If the favorable climate did not provide an equable and adequate rainfall throughout the whole year, the soil would thus very quickly become too dry for the plants." (Table 95, page 426.) "In general the perviousness is so high that at times too much water is rapidly and easily carried off. If these soils were on Java, in a region with a pronounced east monsoon, then they would dry out too strongly and then would appear to have perhaps too small an available water capacity for the tea plants."

This might explain why a deep-rooted shrub like tea can grow well on such soils, while with unfavorable weather shallow rooted crops such as rice and maize rapidly go bad unless they are planted down deep in those ravines where adequate ground water is to be found close to or at the surface.

It is lucky that in the tobacco region, formed by the dacitic and andesitic lahars, and especially in the allochthonous lowlands, the loamy types of soil, with a large content of the fractions V (0.1-0.05 mm.) - VIII (5-2 mu.), especially V (0.1-0.05 mm.) - VI (50-20 mu.), predominate. Thus it is that these soils have an adequate water capacity, can hold the rain water properly by capillarity, and are yet heavy enough to strongly retard the water

124. Cf.: Van Heurn, l. c. (1922), pp. 101-102.

125. Deuss, l. c., pp. 49-50.

126. Deuss, l. c., pp. 51-52.

movement. In a coarser sandy soil the soil water can move extremely easily and thus also sink away, and all too frequently that is why water is lacking just when the plant roots have need of it. In heavy clay much water is present in the fine capillaries but the mobility is so low that when the roots at last have taken it away, water moves in only too slowly. For the roots this merely signifies a lack of water. Loamy sandy soil or fine sandy loam is thus the best for such a plant as the Deli tobacco, which in a short time must grow rapidly. From this viewpoint also, there is then no better soil for its cultivation than the previously mentioned Deli type, which is also found elsewhere in the Netherlands Indies on similar juvenile deposits of fine volcanic ash, such as occur on Java, Bali, etc.

Clays which are so heavy that they may be called "physiologically dry" since the tobacco cannot draw out water rapidly enough from them, hardly occur at all on Sumatra's East Coast. Though the term "white clay sections" is used there, actually the material referred to is always a more or less sand-rich white loam, of which, if clods dry out in the sun they become hard blocks, but never so hard but that they cannot be broken up with the cultivating implements. If the soil really were a heavy clay, in times of long continued drought it would crack open several centimeters broad, and a meter or more deep. I have never observed such cracks in that region. The mechanical analyses also indicate that it is very improbable that such pronounced cracking will be true of any soil type of any considerable extent in these regions.

An important factor in these relationships is also the humus in the soil. Humus raises the water capacity and at the same time increases the mobility of the water. It makes the soil loose and in a humous soil a plant like tobacco can more rapidly form a large root network. It is a onesidedness, a misunderstanding, to consider the good effects of humus only from a chemical point of view. Physically, through its influence on the water supply of the plants its influence is at least as great, probably most times even greater.

But not alone for the water supply of the plants is this movability of water in the soil so important. It is also useful in supplying the plant with all kinds of nutrient substances. Thus we come back to the chemical side of the question. Here we may well touch upon a marked change in the point of view during the last few years as to the taking up of food substances from the soil. Formerly it was supposed that the roots, as it were, drank up the soil moisture. If thus a substance, say phosphorus, occurred in the soil moisture in a concentration of, for example, 1 mg. per liter, and a full grown plant upon analysis of all the parts contained in the whole thing say 10 grams phosphorus or 10,000 mg. then it meant that the plant also must have taken up 10,000 liters of water and except for the perhaps close to 5 liters water, which it contained at time of analysis, it must have transpired 9,995 liters. However this appeared to be impossible, as pot experiments very quickly showed. Then the reasoning ran thus: Per day the plant transpires but 1 liter water; in the 200 days of its existence thus at most 200 liters; that is, but 1/50th of the amount of water needed, hence if the plant is to grow well the concentration of phosphorus would also have to be 50 x greater or 50 mg./liter. At present however, we know that the roots are in no sense obliged to suck up, to drink in the soil moisture as it is, but that up to a certain point they take up what they wish from it, and what is left over, i.e. water, they do not take in. This being the case the same water can do service many times over; after it has delivered its phosphorus to the root it again diffuses away to other places, where it can dissolve some more phosphorus and come back with new provisions to the root tip. But what is particularly necessary is that the water can actually diffuse with sufficient speed back and forth through the soil, or that there exists an adequate water connection between the root tip and the place where the supply of phosphorus lies, so that the phosphorus can diffuse in the water from the one place to the other. In other words, either there should be an adequate water movement in the soil or an adequately ramifying and wide-canal water net, preferably both. Then if there is present enough plant food, and if these plant nutrients dissolve sufficiently rapidly in that freed water, the situation is favorable,

and the plant can get along with a good deal less water from rain or from other sources. This is the case in a light, humous loam, with large pore spaces, but in heavy clay the pores are much too narrow and the diffusion is thus quite inadequate.

Coming back to the chemical analysis of the soil samples, we can now say that it is relatively unimportant whether from one soil somewhat more phosphorus and/or any other plant food materials can be dissolved in strong, boiling acid than from another soil. The real question is: In which soil can the plants get possession of the necessary plant food materials most rapidly and most easily? Such a soil is not necessarily the soil which upon analysis gives the highest figures, although of course an analysis will give some indication. Obviously a plant will not be able to obtain much phosphorus from a soil which upon analysis doesn't give any phosphorus. Yet plants sometimes furnish some remarkable surprises in this direction. This makes problematical the value of the figures "relating to the fertility" (see Table 98, page 485) from Boners, and in general the numerous (1,300) analyses of the Deli Experiment Station during the course of about 25 years. Especially in the case of soils with a large water movement and an abundant supply of water, one must be cautious in concluding that low analysis figures obtained by such laboratory methods indicate a lack in the soil.

Without having figures from deeper horizons as well, it is likewise dangerous to conclude from the chemical analysis of a humous surface soil that the soil at that point is rich. All too often through cultivation and erosion the humous surface soil is lost, and when this happens there is but little connection between the figures for the original surface soil and for the character of the soil remaining. In the case of the chemical analyses by Deuss,[127] which, except for two, about all the 120 are of surface soil (A) only, the aforementioned objection is not so serious, since "most of the pits were dug 1 m. deep." Thus the "surface analyzed is to a depth of 1 m. as only A is given."[128] It will be quite some little time yet before all this 1 m. thickness is eroded away. But if this "surface soil" is not homogeneous, that is to say, if it consists of various layers or horizons, which were only mixed when the sample was studied, then for the practical man the analyses are only of very moderate value.

However such analytical data are many times very useful for comparison. If we place the average, the maxima, and minima of the figures found for total organic matter, matière noire, N in the total organic matter, and in the matière noire, acid-soluble and available P_2O_5 and CaO of the preceding table from Deuss for the Siantar soils along side those of diverse tea soils of Java, then for example the Pengalengan and Patoeha forest soils come out on top[129] (see Table 101, page 490).

But, says Deuss, "the great depth of the Siantar soils enables the plants to profit strikingly by the little humus that there is, and this is shown by the well known luxuriant growth. If a soil is loose, friable, and deep, then even a small percentage of humus can still achieve wonders." The reader can understand that it is especially the ability of the water to move about readily which is here a principal factor.

* * * * *

Let us now pass on to the consideration of a few figures of yield. In the first place it is not out of place to recall that Deli tobacco is not a quantity but a quality product, so that quality is always worked for to a predominating degree. This however does not deny that quantity also plays a role, especially in the lowering of the cost of production per kilogram. In the early days, according to tradition[130] when the plantings could still be made on virgin tropical high forest land, there was obtained from an entire division 16 to 18

127. L. c., pp. 59-126.

128. L. c., p. 58.

129. These averages I have calculated from the table of Deuss, l. c.

130. Figures for years previous to 1898 have not been published.

Table 101

Constituents	Tea Soils of Siantar, (about 120 samples) Sumatra		Pengalengan, (about 24 samples) Java	
	%		%	
Organic matter	4.87	(16.05 -0.63)	9.88	(28.6 -4.0)
Matière noire....................	1.15	(2.31 -0.13)	3.46	(5.30 -1.89)
Nitrogen, total	0.21	(0.76 -0.04)	0.58	(0.80 -0.29)
Nitrogen in the matière noire	0.048	(0.27 -0.01)	0.149	(0.280-0.053)
P_2O_5 HCl soluble	0.025	(0.079-0.006)	0.130	(0.400-0.028)
P_2O_5 Citric acid soluble	0.0061	(0.026-0.002)	0.0192	(0.050-0.008)
CaO HCl soluble	0.161	(0.530-0.022)	0.730	(3.18 -0.10)

piculs per field (from 1,500 to 1,600 kg./ha.). We cannot, however, accept these as average figures. Through modifications in cultural methods (different methods of harvesting and selection) in connection with changes in the requirements of the market (thin, light, and tawny colored leaf), the culture of today cannot properly be compared with that of 50 to 60 years ago. From the annual statistics by Dentz[131] the following figures (Table 102) have been taken:

Thus since 1898 the average yield has been increasing rather than decreasing. Especially is this true for the last few years, since at present there is a much more rigid selection of suitable soil, so that fields with unfavorable soil conditions, promising only disappointment, are left unplanted.

De Vires[132] presents the following comparisons (see Table 103 below).

In Deli De Vries[133] also recorded:

Table 102

	Tobacco Yields	Tobacco Yields
1892-1915 (entire east coast)	10.04 piculs per field, about	980 kg./ha.
1916-1919 (" " ")	10.77 " " " "	1,000 kg./ha.
1920-1934 (4 largest companies)	....	1,015 kg./ha.
1933-1934 (" " ")	....	1,168 kg./ha.

Table 103

		Tobacco Yields
Deli, Sumatra	normal harvest about	1,100 kg./ha.
The Principalities of Java	" " "	1,300-1,600 kg./ha.
Besoeki, Java	" " "	900 kg./ha.

131. Dentz and van der Breggen, Sumatra tabak; later: Sumatra-en-Javatabak. Annual Publication.
132. O. de Vries, Tabak, Onze Kolon. Landb. VIII, 3e dr. (1926), p. 56.
133. De Vries, l. c., p. 21.

174 to 1,480 kg./ha., depending upon the prevalence of disease. Thus these figures fall quite in line with those already above recorded (Table 102, page 490), but show at the same time the great variability in yield of the Deli tobacco fields and hence the difficulty of coming to any conclusions about the particular features of the soil based upon the yields.

With regard to tea we have already sufficiently discussed on pages 481-483 the yields for Siantar from 1923 to 1924; and also the production of rubber on pages 480-481.

It is hardly worth while to discuss in a similar way for Sumatra's East Coast, yields for such crops as fibres and oil palms, because from the literature there is not to be obtained sufficient data bearing upon the productivity of the soil.

* * * * *

And now coming to the agriculture of the native people, the cultivation of rice is the first crop to be mentioned. In the East Coast paddies are found only in Siantar and adjacent country, thus within the liparitic region. Before the occupation of the largest part of the arable area of Langkat, Deli and Serdang by the large scale plantation crops, the most extremely sparse population had land enough available so that they could carry on kaingin agriculture, a type which requires less care and application. Sometime later in Deli a plantation once experimented with paddy cultivation, the results, however, were not favorable.

First in 1913 the natives at Tiga Balata made a beginning by constructing a canal for the irrigation of rice fields.[134] Another district followed. On the initiative of the Ministry of the Interior, the Government took the irrigation in hand, and all kinds of irrigation schemes were then laid out. From the beginning these put to shame the original predictions that the results would not be very good because, according to analyses, both the soil and the irrigation water were relatively poor in comparison with those of the good rice districts of Java. It was a bad guess. I must admit that in the beginning (1915) with respect to these irrigation works neither did I have any high expectations. Later on, however, I endeavored to explain the great success in this way: The soil was, and still is, very pervious; as a consequence in contrast with the soils of Java, where 1 to 3 liters/second/ hectare of water is enough to properly maintain the paddies under water, here 5 to 10 liters, thus approximately 3 times as much water must be applied.[135] In the still relatively loose ground an extensive network of roots can develop. By this means, from the greater quantity of water which can move in the soil, the rice plant obtains an approximately adequate supply of plant food materials. Already, regarding the 1917 to 1920 figures for harvest, Van Heurn[136] stated that the average was 41.4 quintals/ hectare dry paddy, and compared it with Java's figures of 21 to 24.4 qu./ha. Tideman[137] gives figures for (wet) rice per hectare which calculated in the same way, amount to 33.5 to 46.5 qu./ha/ dry paddy for the Bah Korah region, 36 qu./ha. dry paddy for Tiga Belata and Dolok Merlawan, and about 23.5 qu./ha. for Bandar Meratoer (near Perdagangan). Statius Muller[138] accepts finally for the year 1924-1930 for the best region (Panombean)- yield figures varying between 44 and 61 quintals per hectare dry paddy, and for the poorest region (Perdagangan) figures between 22 and 29 qu./ha. dry paddy.

In the Deli Crt. of 28 Jan., 1935 are recorded similar locally representative figures which I have converted, with the following result: "The yield during the last years is 21-49 qu./ha. and averages of 30.5 qu./ha. in 1933 were reached and almost 32 qu./ha. in 1934. For such

134. J. Tideman, Simeloengoen (Leiden, 1922), p. 260 ff.
135. This is still the case; it is however quite conceivable that with a few decades of regular irrigation the perviousness and thus the water requirement will decrease; probably however such a change will be accompanied by a greater fertilizer requirement. Cf. Deli Crt. of 28 Jan. 1935.
136. F. C. van Heurn, Jhr., Grond. Cult. geb. Sum. O.kust, enz (Amsterdam, 1922), pp. 103-104.
137. L. c., p. 267.
138. G. A. L. Statius Muller, Irrigatie t. Oostk. v. Sum., De Waterst.-ing., 19 (1931). p. 310.

regions 36-37 qu./ha. are no longer any exception."

The reader will already have remarked that in the 15 to 20 years that the Siantar irrigation has been in existence, there has been a decline in the average harvests of from about 41 to approximately 31 qu./ha. lowland paddy. The future may reveal what the reason is for this.[139] The harvests are still very excellent, just about as in East Java, but they are no longer so fabulous as in the very first years, when it was still possible to lay out paddies directly on virgin land or at least on soils which had been used only for extensive cultivation. From the nature of the case the like of that occurs but seldom in the Archipelago.

The kaiñgin rice production of the East Coast is in no sense different or outstanding in contrast with that in the other parts of the Netherlands Indies. For Simeloengoen Tideman[140] records: "A good kaiñgin produces about 25 piculs paddy, per hectare," which is about 15 qu./ha. Most probably this refers to liparitic soils.

A definite choice of soils of definite soil types for rice cultivation in connection with the map of Druif, has not yet appeared. Brinkgreve[141] gives a survey of the culture forms in Langkat, he does not however tie these directly to the soil types[142] but rather to the land rights, etc. It is notable that the yields of the several following groups vary so little:

a. Agriculture on free lands along the coast (swamp paddies) 11 to 13 qu./ha. paddy (unhusked).
b. Agriculture on free lands between concessions and forest reserves 13 to 17 qu./ha. paddy.
c. Gardens near larger towns and along the roads--no rice.
d. Paddy on harvested tobacco fields (djaloerans) about 15 qu./ha.[143]
e. Agriculture on allotted concession lands, no djaloerans, 9 qu./ha. paddy.
f. Agriculture on native exchange lands in rubber and oil palm concessions, 18 qu./ha. paddy.
g. Agriculture on allotted lands of tobacco plantations which have been converted into rubber plantations, 13 qu./ha. paddy.

* * * * *

These yields, with an average of approximately 15 quintals per hectare are not high; indeed, they are very poor in comparison with the figures of yields of forest kaiñgins close to the boundary of Atjeh on Tertiary soils, which[144] the first year gave a yield of approximately 35 quintals per hectare, and the second year about 26 quintals per hectare.

The figures for Langkat are in astonishingly close agreement with those which were recorded above on pages 457-460 for the Batak Lands and Simeloengoen.

Finally, if we compare the above-mentioned yields of rice of Sumatra's East Coast with those of the countries which surround the Netherlands Indies (Table 104, page 493), especially when one takes into consideration the well-known intensive cultivation, selection of varieties and heavy fertilization in countries such as Japan and Formosa, then the Siantar paddies make indeed a very good showing. It is now very interesting to speculate as to whether or not in the coming decades Siantar will hold this high place or take a more or less lower place. In either case, the outcome of irrigation undertakings of this nature shows that it is to be reconsidered whether through the laying out of more irrigation systems on similar, but at present still unused land, such as in Tanah Djawa and Asahan, the rice production of the country

139. Since 1929 the Agricultural Extension Service have not published any data regarding the rice culture of Siantar.
140. J. Tideman, l. c., p. 125, already cited on p. 458.
141. J. H. Brinkgreve, Inl. Landb. in Langkat, Landouw VIII (1932), p. 209-241.
142. Brinkgreve, l. c., p. 226.
143. This figure was calculated from Brinkgreve's yield figure of 150,000 piculs for 1930 (p. 234) divided by the estimated number of tobacco fields, for 1929 taken from the tobacco statistics of Dentz and Van der Breggen.
144. Brinkgreve, l. c., p. 229.

Table 104

RICE YIELDS IN ASIA AND MALAYSIA

	Koens [1]	Smits [2]	Wulff [3]	
	Quintals per Hectare			
Japan	36	34	34	quintals per hectare
Siantar	--	--	25 [4]	unhusked dry paddy [5]
Fiji	22	--	--	
Formosa	21	--	--	
Korea	20	--	17	
Java and Madoera	--	17	15	
Burma	--	17	15	
Thailand (Siam)	--	16	18	
British India	--	16	14	
Netherlands Indies as a whole	15 to 16	--	--	
French Indo-China	--	12	12	
Philippine Islands	--	12	12	

1. A. W. Koens, Rijst rondom de Pacific, Kolon. Stud. 13, I, (1929), 304.
2. M. B. Smits, Rijstsituatie, enz., Meded. Afd. Landb., Buitenzorg, 17 (1930).
3. A. Wulff, Rijstproductie v. N. I., enz. Lbk. Ts. 47 (1935), 225.
4. Average figure, calculated from 50 piculs per hectare wet paddy = 31 quintals per hectare paddy.
5. In order to be able to compare these figures with others mentioned in this book, conversion ratios are: 1 qu./ha. upland or hill paddy (gaba) = about 4/3 piculs per bouw upland paddy = about 5/3 piculs per bouw lowland paddy. This is because lowland paddy (grown on flooded land) weighs between 15 and 20% more per unit volume than upland paddy (grown on non-flooded uplands). --R. L. P. cf. footnote 163, page 502.

can be raised considerably and perhaps through that in the course of a long time, more can be raised for local consumption, so that there will be less dependence upon imports.

Of the rest of the native crops, rubber is at present certainly the foremost. It is especially to be found in the west-northwest, in Langkat, but also in the east-southeast, in East Asahan. There is however no soil requirement which determines its extension. Cocos have already been mentioned on page 484. The earlier nutmeg culture and the pepper gardens have faded away.

And finally, just one remark about the future. Regarding the outermost coastal strip, some time ago[145] I remarked upon its significance, referring particularly to Deli and Langkat. With reference to what was said there, I may now merely add that with reference to diking, and draining and bringing into cultivation of this coastal strip, the new map of Druif, (Fig. 180) which has been discussed above on page 471, strongly confirms the earlier good expectations.

* * * * *

5. THE WEST SUMATRA MOUNTAINS BETWEEN THE BATAK LANDS AND THE PIEK VAN KORINTJI

In addition to Sumatra's West Coast, this region also comprises a large part of the Residency of Tapanoeli. It may roughly be described as a strip parallel to the west coast, of approximately 110 to 140 km. breadth, in the north bounded by a line perpendicular to the coast, running over Batang Toroe; and in the south by a similar line over Balaiselasa. Especially because of its topographic, and, in general, its natural

145. E. C. J. Mohr, Tropical soil-forming processes and the development of tropical soils, with special reference to Java and Sumatra (translated by Robert L. Pendleton), National Geological Survey of China (Peiping, 1933), p. 196.

situation the above-mentioned region lends itself particularly to treatment as a unit in a single chapter.

Soil-Forming Rocks

In continuation of the general discussion of the soil-forming rocks for all Sumatra (see pages 416-420), the consideration here can be relatively brief.

If a volcano had never existed in this part of Sumatra the structure of the mountains over this entire region would have remained about as simple and relatively uniform as it is now in that remaining portion of the region devoid of volcanic eruptions or products, between Padang Sidempoean and Pandjaboengan. This part of Tapanoeli Zwierzycki[146] described in these words: "To the south of the Batak Lands there begins the characteristic landscape of the Padang Uplands, namely, high-lying broad long valleys between rounded, relatively low mountain ridges. The mountains are less wild than in Atjeh and are gradually being deforested. The valley of Padang Sidempoean to Panjaboengan, flanked by two Barisan ridges, is probably to be conceived of as a partly filled up depression. Remains of old terraces along the rim and a quite marshy portion near to the drainage outlet of the valley through the Batang Gadis make it seem probable that earlier there was a lake here which has since been drained by the river mentioned, as the result of a long continued cutting down of its bed."

These two Barisan ridges appear to be "block folds of Permocarboniferous rocks." According to Fennema[147] "the western one is built up of granite with mica schists and quartzites while on further north it is made up of normal clay slates with quartzitic masses. The eastern block fold consists of weak clay slates with quartz veins, quartzitic masses and gray limestone." These rocks continue toward Sipirok, and on evidently still much farther northwards, along the east side of the southern Batak Lands (Habinsaran). But they continue also toward the southeast and south-southeast and time and time again crop out from under and up between the stretches covered over by the younger volcanoes, to as far as the southern limits of the region we are here considering.

East and west of the block folds mentioned, in Tapanoeli on the surface over great areas there lie Paleogenic rocks, apparently on Precarboniferous ones. On the east side the Paleogene are mostly coarse and fine grained sandstones with a little mica and then variegated clays. More toward the south conglomerates also occur. Much of this region is still unknown geologically. On the western side, both to the south of Siboga as well as to the north of there on to the boundary of Atjeh, are found similar rocks belonging to this formation. The solid, white or grayish sandstones, south of the lower course of the Batang Toroe and stretching out to approximately the breadth of Panjaboengan, form a closed irregular plateau, into which the rivers have cut deeply (Zwierzycki, l. c.).

Although actually a continuation of only the eastern body rather than the western one, these Paleogenic rocks are also found still farther south.[148] We may say that the large bodies shown on the map are located north and south from Rau, north from Soeliki and Pajakombo, and finally around Sawah Loento, from Fort van der Capellen to nearly to Datoe.

Among the rocks in these southerly lying tracts breccias and conglomerates predominate, consisting of fragments of quartzite, slate, diabase, and quartz, and locally also of granite and limestone. From above downward in the formation the grain size of the deposits decreases. The upper layers possess predominately fine-grained quartz sandstones (with coal between them) but also clay shales and marls.

Neogene formations do not occur on the west side of the portion of the Barisan Mountains here being considered. While on the eastern side there is a great deal of

146. J. Zwierzycki, Toel. bl. I (N. Sumatra) d. Geol. Overz. k. N. O. I. Arch., Jb. Mijnw. (1919), Verh. I., p. 18.
147. R. Fennema, Top. en Geol. beschr. Noord-god. Gouv. Sum. W-kust, Jb. Mijnw. (1887), Wet. God., p. 179.
148. See the map of J. Zwierzycki, Bl. VII der Geol. Overz. k. N. O. I. Arch., Jb. Mijnw. (1919), Verh. I. Toel., especially, pp. 88-92.

Neogene, yet not so much as in Southern Sumatra. On his sheet No. I Zwierzycki sketched a large body extending out northwards to Goenoeng Toewa and Rassau, and southwards along Pasir Pengarajan to Bankinang. Also east from Sawah Loento, at Sidjoendjoeng there are found Neogene deposits. They consist of a bedded complex, of which the oldest is the so-called boundary clay, consisting of clay marls rich in lime (Globigerina), and grayish green or dark in color. Above this are the sandstone layers with increasing grain size upwards.

At this geologic period the volcanoes began to assert themselves. Where volcanoes made their appearance in the locality, from beneath upward the tuffaceous character of the Neogene increases until finally the material consists of nothing but tuffs. While in the northern part, between Pengarajan and Rassau, where volcanoes were lacking and even today are still absent, there are no Neogene tuffaceous materials.

In consequence of volcanic activity commencing in the later part of the Neogene, its more important activity was during Quaternary time.

In the north the Loeboek Raja built itself up, and thereafter the Siboeal Boeali. There ejecta are particularly of more basic materials, andesite and even some basalt. Apparently now and then pale pumice stone ash was erupted, this covering over older formations. Then follows the longest part of the Barisan mountains without volcanoes and thereafter toward the south the Sorik Berapi is the first of this series. Situated more toward the east near Bondjol are the Boekit Gadang and the Goenoeng Mas. Next the Singgalang de Merapi and the Sago occur and then, after a long gap, the complex of the Piek van Indrapoera.

The volcanic products, both as lava streams and also as coarse and fine fragmental ejecta, which have been strewn out over the land, have in the past played a significant role in soil formation on Sumatra's West Coast, and they still do today. This is the reason for somewhat closer consideration of these products.

As to the petrography, Verbeek in his classic work[149] dealing with the west coast has already established the most important data. About 65% of the rocks studied[150] were augite-andesites. About 10% were olivine-containing augite-andesites; only a few appeared to contain hornblende and they were especially older magmatics (Young Tertiary). Basalt occurs also here and there, in other places pekstones. In the Quaternary there were also mighty pumice stone eruptions especially in the center from the volcanoes Manindjau, Singgalang, Merapi and Sago. Possibly, however, there were also eruptions from Siraboengan or Boekit Gadang.[151] This pumice stone (in the above-mentioned work Verbeek repeatedly places the emphasis on the pumice stone) has not only a much higher SiO_2 content than the rest of the rocks, but also a very notable content of sanidine, so that it cannot be separated by air or water methods from andesitic efflatas, though it must be conceived of as a completely different rock, coming from an entirely different "magma furnace" than the andesites and basalts. Various obsidian occurrences are connected with the pale, more acid pumice stone tuffs. Though everyone knows these tuffs from the Karbouwengat at Fort de Kock (see Figs. 18, page 138; 187, and 188 pages 496-497), yet a complete chemical analysis has never been made of them and we know nothing except what Kemmerling has written[152] regarding the mineralogical nature, as follows: "From the petrographic study it appears that particularly the Goenoeng Tandikat has ejected quite acid rocks; basic representatives were not erupted." This is indeed directly in line with the conception which is to be obtained from Verbeek's work for the Padang Highlands in general. Also Fennema pointed out that "especially on the western side of the Manindjau mountain, except in the environs of Loeboek Basoeng, obsidian and pumice stone occur." If the geological mapping now going on along Sumatra's West Coast will be continued and the gaps with

149. R. D. M. Verbeek, Top. en geol. beschr. Sum. Westk. (Batavia, 1883).
150. L. c., p. 514.
151. L. c., p. 641.
152. G. L. L. Kemmerling, Vulkanol. Meded. No. I, p. 24.

Photo by André de la Porte

Fig. 187. Sumatra's West Coast. The Karabouwengat canyon in the pale Agum tuffs. All irrigable lowlands transformed into paddies. The soil is fertile, hence even steep slopes are clothed with forest.

respect to the rock analyses will be filled up, we shall perhaps still have many surprises. (Compare the general introduction to this part, pages 417-418.)

Climate

Along the coast (Table 89, page 421, from Sibolga to Balaiselasah) the climate is continually humid. During only few of the months does the rainfall average ever fall below 200 mm. and never under an average of 150 mm. On the slopes lying back from the coast, but still facing the sea, it rains still more (Table 90, page 422) from Loeboekbasoeng to Oeloelimaumanis; compare also Fig. 189, page 500). On the contrary the long narrow valleys (see Table 91, page 422 from Sipirok to Soempoer) have a distinct dry season from June to August, with a much lower total for the whole year. Even when the total rainfall exceeds 2m. (see Table 92, page 423 from Padang Sidempoean to Moeara Laboeh). July is still relatively dry, although not so much so that the month could be called "arid."

On the basis of observations made during a long series of years in the region under consideration there are thus but few places where it is possible to speak of regular, recurring drought. If the soil material be pervious, at most there is intermittent leaching. It is not possible that alternating weathering could take place, that is to say, alternating sinking down and rising of soil moisture; the dry spells which occur are quite too short for that. For that matter over the entire region the conditions of continuous leaching are predominant.

As would be expected, with differences in elevation between sea level and about 3,000 m. the temperatures naturally vary widely.

Photo by Leeksma

Fig. 188. Sumatra's West Coast. Close to the upper rim of the Karbouwengat. Shows differences in the tuff; younger efflatas from the Merapi, perhaps more basic, lie above older, paler, less fertile ash.

Weathering Processes and the Resulting Soil Types

Under climatic conditions which are relatively uniform except for the temperature and for the elevation, it is obvious that the differences in soil types are indeed principally dependent upon the parent material, the rocks. As to stages, we may expect all of them, from juvenile to senile.

Here again the principal question of course is: Are there (young) volcanoes in the neighborhood or not? Beginning with the non-volcanic stretches, such as the clay shales and sandstones of Permocarboniferous or Eogene age, we can hardly speak of an intensive chemical weathering. With or without taking up water, these rocks disintegrate in proportion to the clay content. They change back into just what they once were: sand, loam, clay. But the new clay, loam, or sand soils are in a way far different from the original deposits, because during their reforming they have been exposed to a very great amount of leaching. Supposing, for example, they had been originally deposited under the sea, then the clay was absorptively quite well saturated, while all kinds of lime-gathering organisms sank down and accumulated with the deposits on the sea bottom. The new soil weathering from these rocks, for example, in the great region between the mountains of Tapanoeli between the Loeboek Raja and the Sorik Berapi, must thus carry poor kinds of soil, for during the new weathering the colloids must have been strongly leached and a considerable portion of the lime also dissolved out.

If there was iron in the deposits, then through oxidation the gray and greenish gray colors have been transformed into pale to darker yellowish gray, light brown, and light red. The natural vegetation is forest, although it is by no means luxuriant forest. Where man has cut the forest down, it grows up again very slowly. The forest practically never comes back in the large grass plains, the cogonals, which from time to time are intentionally or unintentionally burned off by the natives.

As a consequence, on all slopes and convex terrains there are pale yellowish gray lixivium types of soil. Since they are coarse sandy, and thus quite pervious, these types are very apt to erode seriously. Consequently all slopes at all steep are strongly eroded, hence the soil which is left can hardly be deep. If, however, the soil types originated from (heavy) claystones which have weathered back directly into heavy clay, then the water movement in the soil is difficult and irregular. These clays are frequently variegated; here bluish gray, there deep red flecked, thus an expression of the transition toward amphibian soils, although in nature their formation is also different.

The higher the soils lie obviously the higher the humus content of the surface horizon, which makes this horizon gray, and in the high mountains even dark gray to brownish black. Also under a grass vegetation this surface soil becomes dark, but due to the repeated burning off the color is more of a black than a brownish black. In a certain sense this is rather an artificial than a natural influence. Because humus increases rather than decreases the susceptibility to erosion, a high humus content is not attained. The humous surface soil is more rapidly lost than that which is poor in humus, and washes off toward the valleys where it is deposited to form a relatively richer soil type than its parent soil was. An example of that is the plain between Padang Sidempoean and Penjaboengan, which is quite similar to the Atjehian examples (see pages 429, 432). Also to be compared with this is the plain of Loeboek Sikaping, and perhaps still many smaller valleys or plains, for example in the Upper Rokan and Upper Kampar stretches.

The weathering proceeds differently on the old eruptive rocks, granite and diorite on one hand, diabase and gabbro on the other. Here is not merely disintegration, but rather weathering of the minerals, as described on pages 71-88. But since these rocks, like igneous rocks, are hard, compact, and weather slowly, the result is that erosion just about keeps up with the weathering. But where some soil does remain in place it is, in so far as it does not consist merely of loose quartz sand, a severely leached out and senile lixivium. Thus the soil on the old hard eruptives is not all much richer than the soil on the previously mentioned sedimentary rocks. Only where tropical high forest, undisturbed by man, has been able to develop and maintain its position tranquilly down through the centuries is this forest superior to that on the sedimentary rocks, hence the humous surface soil so conserved is consequently richer. However, where quite a long time ago man chopped down the forest, the landscape of tall grass (<u>Saccharum spontaneum</u>) and cogon (<u>Imperata</u> spp.) is just as poor. For example, note the environs of Moeara Sipongi where the highway runs over granite. Note, also, the granite mountains along the highway near Taroetoeng, close behind Sibolga. Between the miserable grasses where the terrain is rounding and sloping one sees the slightly humous, pale grayish yellow lixivium ground. But where through being more nearly level the soil is less eroded off, it is browner and redder. Of course, again the best of the land lies in the valleys, in so far as it has not been carried away to the coastal plain and into the sea by the rivers in the form of extremely finely dispersed, colloidal sediment. This last process, however, only occurs where there is a certain poverty in calcium, both in the silt and in solution in the water. If there be adequate Ca in both silt and water, then much more alluvium settles out in the first valleys the stream flows through. But Ca cannot come from the quartz sandstones nor can it come from the clay slates. And it has long since been dissolved out of the soils on the eruptive rocks mentioned--most of it comes from the marls and from the limestone reefs, which occur in the Permocarboniferous as well as in the Eogene formations.

This limestone occurs in many places in long walls, rising up very high almost vertically--serious obstalces in highway construction. And since the rain which falls on these limestone masses vanishes directly into numerous cracks and flows away in subterranean passages, the soils on top are to a high degree infertile, yet there is still a marked indirect significance. Though infertile and almost uninhabited, this limestone makes the abovementioned valleys more fertile and thus

better and more capable of being more thickly inhabited.[153]

And now coming to residual soil types on volcanic parent material, in the first place they are based upon the difference between solid, compact rocks and loose lava and efflatas. It is difficult to point out the fragmental material which resulted from the older, Tertiary volcanic activities, but the andesitic and basaltic rocks, the molten magma which had flowed out calmly and then congealed as hard, solid masses have been more resistant to weathering and erosion so that at a number of places in the district we are now considering, they occur in the landscape as knobs and larger and longer masses more or less in rows. Here they weather very, very much more slowly than more acid eruptive rocks, so that the soil covering does not accumulate to any notable depth except on a few extensive, flat portions, and these are infrequent. As a rule the soil is far from being a deep one. Yet the fertility is so low that except perhaps on the almost vertical portions, natural forest is allowed to remain on it, for the land is not worth kaiñginging. But where the forest has been destroyed, it never has another chance to develop anew. Man and erosion take good care that this does not happen! On the recent lava streams one also sees the same condition: little soil, little vegetation.

The terrains developed from loose efflatas present an entirely different picture, whether the material lies on the place where it fell from the air and remained, or whether the efflatas had been transported by water, either as lahars or in the course of less catastrophic erosion. Regarding the differences in composition of the rocks, enough has already been said above (see pages 494-495). The same is true of the climate (see page 496). The divergences in the forms of the continuously leaching-type of weathering are, as a consequence, but small and at most the variation is to an intermittent leaching. The result is a pale yellow to brown juvenile lixivium, the intensity of the color being in proportion to the iron content of the parent rocks, and in all stages from fresh to viril. On the Singgalang, for example, we find no red, only pale yellow to brownish yellow lixivium. Yet here and there the soil is weathered out and senile, but the conditions for becoming red (dehydration) are at the minimum. The material never dries out (see Fig. 189, page 500), there is never a high salt concentration in the water circulating in the soil, so that the iron hydroxides remain highly hydrated. Such kinds of soils, already formed in the Tertiary, subsequently submerged in the sea and then later again exposed above the sea[154] were, while in the sea water, dehydrated as regards their iron hydroxides and are thus red. With reference to the so-called "marine diluvium" of Sumatra, Fennema[155] says "This consists of horizontal masses of red clay with fragments of quartzite"; while Verbeek records[156] "Between Tikoe, Soengei Limau and Loeboek Basoeng the tuffs contain not only pumice stone and andesite, but also bits of obsidian and much red, volcanic clay." Thus in the marine tuff, still far from senile, there is already "red clay," and a few hundred meters higher up, on the slopes of the Singgalang, only brownish yellow lixivium.

The pumice stone tuffs of Fort de Kock (see Figs. 18, 187 and 188) Verbeek[157] calls "white or yellow," not red. "In many pumice stone fragments it is possible to recognize with the naked eye sanidine, biotite and sometimes also hornblendes." It is certainly not surprising for these materials to remind us of the liparitic tuffs of the Batak Lands and those of South Sumatra, to be mentioned farther on. But as already said, analyses are still lacking and resemblances cannot be proved.

Meanwhile the soil, itself, also shows clearly points of similarity, especially if we compare the plateau of Old Agam with the plain of Silindoeng. Neither

153. Cf.: Fennema, l. c., pp. 176-177.

154. Cf.: Verbeek, Sum. Westkust, pp. 523-525.

155. Fennema, l. c., p. 228. The word "diluvium" has now been given up as improper as applied to the Netherlands Indies' Old Quaternary deposits.

156. L. c., p. 529.

157. L. c., p. 531.

Fig. 189. Moss and fern vegetation of the mossy forest on the Singgalang, at about 2,000 m. elevation, Sumatra's West Coast. Optimum conditions for intensive decomposition of the plant remains. (See pages 107-108.)

of the two formations, however, is pure pumice stone tuff, since both have been deposited in and by water and as the Silindoeng tuff is polluted--if one may put it that way--by erosion products from the mountains surrounding this plain, among others from the old andesitic peaks, already mentioned above (page 456), and also from some older, sedimentary rocks in the northeast. Likewise the Agam tuff is also mixed with, and even here and there clearly covered over by (see Fig. 188) more or less basic products of the youngest of the volcanoes, the Merapi, yet at the same time with some older material. "The occurrence of rounded granite and schist cobble stones in these pumice stone tuff layers makes it apparent that the tuffs have been deposited from water and are not sediments coming directly from the air."[158]

Similar tuffs are found in the plain of Pajakombo, which is drained by the Sinimar river with its tributaries in the same way as the Si Anok with its tributaries drains the plain of Agam. But the erosion valleys are not so deep nor are the walls cut down so nearly vertically.[159]

The reader will understand that on such porous tuffs neither amphibian nor subaqueous weathering forms can easily occur, both because the perviousness is too great for these conditions and because the situation is as a rule too high. But such forms do develop, especially where the poverty in iron is great and but slightly pervious pale clay has developed. Otherwise wouldn't it be true that the laying out

158. Verbeek, l. c., p. 530.

159. According to Verbeek, (l. c., pp. 537-38) these vertical walls originated through erosion at the foot, with at times caving off up to the top of an over-lying mass of tuff. The rainwater seeps down through the tuff and first erodes out the lowermost portion. While it seems to me that this could quite well happen to an entirely loose mass of tuff, it seems more probable that from more or less hardened tuff, through swelling of weathering clay in vertical cracks, at times pieces of tuff are pushed off and then fall down to the bottom. (See Fig. 18, page 138 and Fig. 187, page 496.)

of paddies on such terrain would be practically impossible? In a certain sense amphibian conditions do occur in these centuries-old paddies but there has not yet formed under the paddies a layer of iron concretions, as the quantity of iron oxide is too small for that. However, the silicic acid dissolved in the upper portion of the profile precipitates in the deeper horizons and there hardens the tuff.

Meanwhile in the lowlands along the coast, for example northwest of Ajer Bangis,[160] quite similar subaqueous weathering layers in the soil may be found. According to the description by Smits, sandy deposits preponderate in the alluvia. The subsoil of some of them "consists of strongly bleached-out gravel, in which are quantities of stones rounded by water action. This material is made up principally of fragments of schist and quartz and also of very white weathered andesite." According to the nomenclature we are here following, these sand and gravel masses certainly should not be called alluvium, but colluvium. The alluvium which came along with it could not remain on the steep slopes toward the sea, but has been carried on into the sea, there flocculated out, and in part deposited perhaps elsewhere along the coast. Back of these sandy coastal deposits, which are similar to those with which I had become familiar in the environs of Sasak, there occur other soil types, which now should be called autochthonous subaerial weathering forms derived from allochthonous deposits of volcanic material (especially sand and gravel)**((V.b.2. col)--H.NN.ae. (I-3))**. Hence they are very good; "the ground is humous and brown in color with an excellent, not too sandy structure" (Smits, page 5).

Allochthonous heavy loam and clay soils are seldom if ever found in this region which we are now considering. All the most extremely fine soil material, when once it has been suspended in water in the mountains for a long time doesn't again have a chance to·sink. It is carried on and away with the rivers westwards toward the sea or, if eastwards, part may also reach the sea (Malacca Strait, etc.), while part of it settles out on the lowest spots in the extensive lowland between Bilah and Djambi.

Evaluation and Utilization of the Soils

By and large in the region we are here considering the evaluation and utilization of the soil are entirely in agreement with what may be deduced from the data of the preceding pages. A glance at the map compiled by the Census Office 1930[161] relating to the density of the population of Sumatra, also gives an idea of conditions which may be stated approximately in the following words (the figures in parentheses indicate the number of inhabitants per km.^{2}). First there is the quite densely populated subdivision of Silindoeng (58) bounding to southwards the subdivision of Sibolga (27) and Angkola (28), where the volcano Loeboek Raja still exerts an influence. Then more to the south follows the subdivision Mandailang (27) with the plain of Great Mandailang into which the best of the material from the surrounding mountains has been washed together. From among other mountains in the south eroded material is from the Sorik Berapi. But east and west from the Padang Sidempoean --Panjaboengan strip lie the poor mountain and hilly lands of Natal (8) and Padang Lawas (9). Next to them, with somewhat more volcanic material follow the subdivisions Ophir (19) and Loeboe Sikaping with an alluvial plain (16). And now we come into the true Padang Uplands with the Merapi volcano as the central point. All three of the subdivisions Oud Agam (237), Fort v/d Capellen (169), Batipoeh and X Kota (152) touch the Merapi peak. Manindjau (72), Soeliki (92) and Solok (99) lie somewhat farther from it, but yet extend over (somewhat older) volcanic soil types. Eastward from Soeliki (92) via Pajakoembo (48) the country is more and more thinly populated, Bangkinang (18), then Kamparkiri (2.7), and finally Siak (0.88). These numbers speak for themselves. Where there is nothing to be obtained from the soil, nobody lives there, not unless there is some other way of making a living, such as

160. M. B. Smits, Meded. Landb. voorl. dienst No. 2 (1919), p. 4.
161. Census 1930, Dl. IV, Inheemsche bevolking Sumatra (1935), Table 9 and map following.

commerce (Padang) or mining (Sawahloento). Still to be mentioned are the subdivisions lying along the coast, i.e., Pariaman (169) and Padang (204). Without the town, however, the latter is only 132. Likewise, through the subtraction of the inhabitants of the main towns the population figures of a few other subdivisions are considerably reduced:

Table 105

EFFECT OF TOWNS UPON POPULATION OF DISTRICTS

Subdivision	Sibolga e. O.	from	28	to	20,	without	Sibolga	town
"	Oud-Agam	"	237	"	219,	"	Fort de Kock	"
"	Pajakoembo	"	48	"	46,	"	Pajakoembo	"
"	Batipoeh and X Kota	"	152	"	131,	"	Padang Pandjang	"
"	Padang	"	204	"	132,	"	Padang	"
"	Solok	"	99	"	94,	"	Solok	"
"	Sawah Loento	"	110	"	72,	"	Sawah Loento	"

But even subtracting the town population does not alter very much the general features of the distribution of the population. Further on toward the south are regions without young volcanic activity: subdivisions Painan (38) and Alahan Padjang (31), and then Moeara Laboeh (13), Sidjoendjoeng (11) and finally the subdivision Korintji-Indrapoera, although the Piek van Korintji is still an active volcano, a figure of (18) makes quite a poor showing. We may therefore expect that now that more good roads have been constructed in this region. The resulting increase of settlement will in the future give significantly higher figures.

The above figures are still really too rough. This is because many subdivisions include fertile, thickly settled localities as well as infertile, uninhabited tracts. But calculation according to smaller units, the districts, is still not possible because on the available maps the district boundaries are not completely shown.

It would also be very interesting to go into the question as to what percentage of the inhabitants, both of the men and of the women, in the districts which differ according to soil and climate, are cultivating their own land. However not only are there still too few published data in map and letter press on this subject, but such a study would probably lead us too far afield, because there are probably too many other factors which play a part in such a question, but which have little or direct connection with the soil.

* * * * *

A more direct criterion of the fertility of the soil may be found in the figures of the yield of rice. For comparison, we can accept that as an average harvest for Java during the years 1922-1930 almost 20 qu./ha. paddy.

Although there has never yet been a complete survey of this question in the reports of the agricultural extension agents[162] we find a number of figures[163] which throw some light on the matter.

In the Sipirok region we find notable extremes. Going along the road from Sipirok northwards to Sipogoe one gets farther and farther away from the relatively young and basic volcano Siboealboeali. This is shown in a series of cutting tests during the year 1917. In the west-southwest part of the plain of Sipirok, a yield of 51.4 quintals/hectare was obtained. In the same plain but in the east, near Praoe Sorat, against older sandstone and old

162. Jaarverslagen v/d Landbouwvorl. dienst (1917-1925), Verslagen Afd. Landbouw (1926-1929); Verslagen van Veldproeven (Bemestingspr. enz.), 1930 until this year (1935).

163. For Tapanoeli and Sumatra's West Coast these are always given for paddy (unhulled); but whether it be lowland, (irrigated) or upland (unirrigated) paddy is not always recorded. Lowland paddy is usually between 15 and 20% heavier per unit volume than upland paddy. (cf. note 5, Table 104, page 493.)

limestone tuffs, 35.7 qu./ha. was the yield. More northerly, near Djonggol Djae it was 33 qu./ha. Still farther, near Hanopan it was 16.5 qu./ha. Finally near Lantjat Tongah it was 12 qu./ha. In 1919 paddies near Sipirok gave respectively 26, 23.5 and 32 qu./ha. The above figure of 51.4 qu./ha. is presumably exceptionally high for ordinary fields, though it may be expected of native fields heavily fertilized with village manure. In 1923 fertilizer experiments were laid out on paddies near Hanopan where the "unfertilized" plot did not even produce 0.40 qu./ha. while with 87 kgs. per ha. ammonium sulfate and 43 kgs. double superphosphate, 22 qu./ha. were obtained. At the same time even the check plot of a similar experiment near Sipirok produced nearly 26 qu./ha. and with the above fertilizer as high as around 37.5 qu./ha. This is certainly an indication that N and P are the limiting factors. The natives use great quantities of village manure; as much as 600 kerosene cans, = 10 m^3 was applied per bouw (14 m^3. per ha.). They then obtained harvests of between 13 qu./ha. at Hanopan and 26 qu./ha. at Sipirok, but even so this remained still far below the yields obtained from the use of artificial fertilizers. It is thus evident that in these tracts it is worth while for the natives to go in for N and P fertilizers.

In 1924 a repetition of the experiments of 1923 confirmed the results with even higher yields, possibly because of better irrigation water and weather conditions:

clearly that the limiting factor in this region was predominantly P, for when P fertilizers were added, thus without extra N fertilization, the yield in Si Dangge village was raised from 7 qu./ha. to 30 qu./ha. and in Baringin village from 14 to 32 qu./ha., while the natives with their heavy manuring with village manure raise their yields to about 30 qu./ha.

Taking it all together we can thus say that the soil plus the irrigation water close around Sipirok, especially south and west from there, can give harvests of approximately 30 qu./ha. dry paddy. This is because of the source both of the soil and of the irrigation water. Yet it is still apparently P which is in the minimum and next to that also very likely N, in view of the enormous success with these fertilizers. But that great success demonstrates that the other soil conditions, water supply, physical condition, etc., are especially favorable. The further we go out from the region of basic rocks, however, into the liparitic and especially the older limestone and sandstone regions, the more bitter the P deficiency becomes, until finally no rice at all can be produced without P fertilization.

Coming now into Angkola, the country is entirely under the influence of the Loeboek Raja volcano, both as to the soil and as to the irrigation water. Also here there is apparently no excess of either P or N. Near Batoenadoea, for example, where the natives, just as in Sipirok, raise the yield to 30 qu./ha., in an experiment in 1929-30, the unfertilized check plot gave 27 qu./ha.,

Table 106

EFFECTS OF FERTILIZERS ON RICE YIELDS

	Sipirok	Hanopan	Hoeta Padang
	quintals per hectare		
Unfertilized	30	0	0
Village refuse	42	17	21
30 kg. ammonium sulfate and 62 kg. double superphosphate per hectare	49	37.5	34

In 1930 the comparison between unfertilized and the application of 87 kg. per hectare double superphosphate indicated but 43 kg./ha. ammonium sulfate and 87 kg. double superphosphate per hectare increased the yield to 43 qu./ha. Near Losoengbatoe

the soil appears to be richer. The natives obtained yields of 35 qu./ha. in the 1929-30 experiment, presumably through better preparation of the land (hand digging as contrasted with plowing). Even the unfertilized plot yielded 43 qu./ha., a figure which was raised by the use of 87 kg./ha. double superphosphate to 49 qu./ha. dry paddy. The Hoeta Imbaroe experiment gave the same picture. That is, the unfertilized plot yielded 37 qu./ha., while P fertilization of the seed beds alone yielded 44 qu./ha. Here there are also areas with marked P deficiency. For example in 1928 an experiment in the neighborhood of Batoenadoea gave the following: unfertilized 12 qu/ha., with 87 kg. ammophos per hectare: 31 qu./ha.; the same experiment repeated near Boengabondar: unfertilized 14, while with 87 kg. double superphosphate and 43 kg. ammonium sulfate 37 qu./ha. Everywhere we see the same condition: an excellent paddy soil with a deficiency which is easily remedied. The better preparation of the land in 1917 at Batoenadoewa raised the production from 23 to 30 qu./ha. and near Pidjarkoling from 27 to 33 qu./ha. But if we ascend to higher elevations, for example at Pagaroetan, near the pass in the road near Sipirok, then the different climate tends to decrease the production, namely, without fertilizer to 8.7 qu./ha., using village manure this can be raised to 19 qu./ha. but even with the use of 87 kg. double superphosphate and 43 kg. ammonium sulfate to only 32 qu./ha.

Near Sibolga (in Siboelan, village Poring) however the soil is lower in quality. Also, no young volcanic parent material is found there, but instead granite and sandstone. Here in an experiment in 1930-31 the unfertilized plot produced 17 qu./ha., 87 kg. ammonium sulfate brought it up only to 23 qu./ha. and 87 kg. double superphosphate to but 22 qu./ha.

Now as to the plain of Mandailing, the low rainfall (Table 90, p. 422) has been an advantage, for as a result the soil is more fertile. Near Panjaboengan, for example, yields of 41 quintals/hectare (1918) are no rarity. Some varieties even yield as much as 48 and 52 qu./ha. Hagreis and Vonk state[164] that while Angkola and Lesser Mandailing can be estimated to yield 26 to 30 qu./ha. paddy, the plain of Greater Mandailing produces 44 qu./ha. and, adding more ammonium sulfate or double superphosphate frequently gives no increase in yield. This soil is thus a very rich and productive alluvium, which has been accumulated by the affluents of the Batang Gadis river from Precarboniferous, from granitic, and from young volcanic terrains.

Somewhat southerly, in Kotanopan, the fertility is significantly less. The figures of yield which have been obtained lie between 15 (an experiment in 1930 near Maga) and 35 qu./ha. (an experiment in 1930 near Pakanten), but in comparison with the Java figures they are still far from being bad. The great difference between Tapanoeli and Java, however, lies in the fact that in Tapanoeli the mountain slopes are apparently considered to be of very little use, for the inhabitants settle in the plain and remain there; while on Java, on the contrary, it pays to lay out paddies high up on the slopes. How poor the mountain slopes here in Tapanoeli really are is shown very well by the surroundings of Moeara Sipongi. The sporadic paddies in the small valleys along the upper course of the rivers must be more or less sandy and so can thus not be rich. The somewhat larger plain of Kota Nopan receives a little more fine, fertile sediment and the still larger plain of Panjaboengan even more. In confirmation of this the following figures of yield are recorded in some Memoranda of Giving over Charge of administrative Officials (of 1930): Moeara Sipongi 17 quintals/hectare, Kotanopan 20 and Penjaboengan 30 qu./ha. These figures closely coincide with the characteristics of the terrain which have already been described.

There are not many paddies in the Natal subdivision. According to the results of harvesting tests the yields are lower than those of Kota Nopan and certainly far below those of Mandailang. The same can be said of the few paddies in Padang Lawas.

With respect to the Ajer Bangis subdivision, Smits wrote an exhaustive report[165] in which figures relating to the <u>yields of the kaingins</u> are of interest.

164. B. J. Hagreis and H. Vonk, "Landbouw" III (1928), p. 697.
165. M. B. Smits, Meded. Landb. Voorl. dienst No. 2 (1919), p. 4-6, (with map).

I. Recent alluvium, more or less mixed with volcanic material from the G. Malintang, as well as some material of quartzitic origin, thus sandy. It is fertile in so far as it occupies a subaerial position and is humous, and yields 26 quintals/hectare paddy (rough rice).

II. Old alluvium, called by Fennema marine alluvium. More southerly, the so-called Oedjoeng-Gading land, brown, humous, with an excellent, not too sandy texture. It is principally of volcanic origin. At present it is poorer in P than the youngest alluvium, and yields 22 qu./ha. paddy.

III. More in the west the so-called Aier Balam land, light colored, sandy. The subsoil is strongly bleached gravel. Thus apparently it has been exposed to subaqueous or amphibious weathering. There is a higher percentage of fragments of schist and chunks of quartz. All crops which require quite a good deal of P for their production do very badly or only tolerably on this. Forest kaiñgins yield not more than 17 qu./ha. paddy.

IV. A soil of mainly volcanic origin including hilly land above 120 m. Soil of excellent structure, but not particularly fertile yielding not more than 17 qu./ha. paddy.

V. Hilly schistose land, from which the volcanic covering has eroded off. The worst land of the inhabited regions, yielding not more than 13 qu./ha. paddy.

VI. Volcanic mountains of the Malintang. Where not cultivated too long, there is an excellent humus layer, but the soil has been strongly leached by continuous heavy rainfall. Paddy grows luxuriantly but the yield is always quite the opposite.

VII. Schist mountains in the north, as good as uninhabited. Red, infertile lixivium with a tendency to slide off, occurs here. Its value for cultivation is very slight.

The above is Smits classification. Here in a single political subdivision we see a striking series of observations of the different soil types according to the parent rocks and according to the stage of weathering in which the material now is. There is at the same time a correlation with the yields and in consequence the way in which and extent to which the soil is utilized.

Meanwhile, the recorded figures are by no means high. According to test cuttings, the average yield for 1926 for the entire Padang Uplands was about 29 quintals/hectare paddy. The following year this amounted to about 30 qu./ha. In 1927 Fort de Kock and environs produced yields around 35 qu./ha. paddy.

In 1919 it was recorded that in Oud-Agam figures such as 70, 68, and 75 quintals/hectare upland paddy were by no means uncommon. That is a whole lot more than is obtained in Ajer Bangis, and this fact makes it understandable why Ajer Bangis is so much less thickly populated than Oud-Agam.

It is notable that while in the Padang subdivision, according to tests of 1924, Tjina paddy yielded 24 to 44 qu./ha. dry rough rice and in connection with that the general remark was made that "the yields from this kind of land are not second to any," while in the subdivision lying next to it, Priaman, the farmer "struggles to raise the average yield to more than 17 qu./ha."[166] The reasons, however, are in plain sight. All good lands were planted with cocos, which with good prices for copra gave the natives a better living than did the cultivation of rice. It was due to this that the irrigation remained very backward and for the greater part the cultivation of rice is dependent upon rain-fed paddies located on somewhat higher lying land which, moreover, is very pervious, with the natural consequence of numerous failures of harvest, which are to be ascribed to a lack of water.

The Memoranda of Giving Over Charge of the Administrative Officials contain here and there also some data of value in connection with this argument. Thus Controller Stelma records[167] that "the subdistrict Loeboek Sikaping with its miserable, porous lands" is not valued highly, which is understandable in view of the

166. J. B. M. de Lyon, Mem. v. Overg. O. a. Priaman (Febr. '33), p. 49.

167. H. L. Stelma, Mem. v. Overg. o. a. Loeboe Sikaping (Nov. '32), pp. 4-5.

large proportion of sandstones, granite and limestone in the surrounding country. On the contrary Rao, with Koelaboe volcano in the background, and Bondjol, already lying on volcanic terrain, both produce an export surplus.--Controller Hangelbroek[168] evaluated "the kinds of land of Soeliki in general to be of second and third quality, while in a few villages the land must even be called very poor, for example in Mahat." No wonder--Soeliki has not received much ejecta from the Merapi, from the northwest some (acid) pumice stone has been washed out into the plain and Mahat lies entirely on Paleogenic sandstone, etc. Yet "for the irrigated paddies of the Sinamar valleys average yields of 26 qu./ha." are recorded, and "for the unirrigated and relatively poor lands (frequently these are calcareous) of the mountainous portions, average yields of 22 qu./ha." These data also agree with the other information, but "in the Bangkinang subdivision the rice harvest is grievously small." Directly corresponding with this the density of population falls from 92 in Soeliki to 18 in Bangkinang.

That the subdivision of Fort van der Capellen stands in an entire class higher is clear from Controller Morsink's[169] statement that "the stretch between Merapi and Sago is extremely fertile" and that "the production of about 35 piculs per hectare" (about 22 qu./ha.) "can still be raised significantly." The reason is that the paddies are still in part dependent upon rain, and as the rainfall is irregular, many crop failures occur.[170] Although the strip is densely populated and here and there appears definitely to have too few paddies, yet there never exists a fear of shortages of foodstuffs. Also the northern part of the subdivision on the slopes of the Goenoeng Sago is particularly mentioned as being suitable for agriculture but "in the neighborhood of Singkarah Lake" (much sandstone, limestone, etc.) "the lands are sandy and quite infertile." The connection between soil and culture fits strikingly. Also with what has been stated by Controller Stolk[171] relating to the Solok subdivision, which is in the north, adjoining the "infertile" part of Fort van der Capellen, next to district Soelit Aier, also located on these Tertiary rocks, "produces too little rice to supply its needs." But the districts of Talang and Solok with volcanic soils "have even an excess."

In Alahan Pandjang the cultivated land is concentrated in the surroundings of the main town and paddies are found as high as 1,500 m. above the sea. There the paddy stands as long as 9 months in the field and even then gives an outturn of not even 5.0 qu./ha. The soil is a senile brownish yellow to brownish red lixivium, and its poverty is clearly demonstrated by the miserable natural vegetation of grasses and many ferns. In the mind of the unsuspecting person who sees the intense black surface soil, there are raised delusive expectations of excellent fertile humus which, however, does not exist. We have already come across analogous "dazzling examples" in Flores, Atjeh, and the Karo lands.

In Moeara Laboe rice cultivation is limited to the stretches along both sides of the highway between Lolo and Loeboek Gadang. Yields are moderate, perhaps 13 to 17 qu./ha. paddy. That the old mountain, east from the long narrow valley, does not have much which is attractive from a standpoint of agriculture, is comprehensible. But it now appears that the mountains lying to the west from there, given on the geological map as "volcanic," likewise give no inducement for the settling of an agricultural population. The vulcanism must have occurred very long ago, otherwise the soil would not be so senile and so poor.

Finally we come into Korintji where, thanks to the activity of the group of volcanoes to which the Piek van Indrapoera belongs, we again find "yields of as high as 60 qu./ha."[172] While in many other stretches of the entire region here being dealt with, it may be the case that there is definitely a pinching P deficiency.

168. Hangelbroek, Mem. v. Overg. o.a. Soeliki (Mei 1934), p. 34.
169. J. M. J. Morsink, Mem. v. Overg. Fort v/d Capellen, (Juli, 1932), pp. 5-16.
170. H. F. J. Pothast, Mem. v. Overg. Fort v/d Capellen (Oct., 1930).
171. W. C. Stolk, Verv. Mem. ond. afd. Solok (Mei 1931), p. 14.
172. Jaarversl. Afd. Landb. (1929), p. 275.

Here on these younger volcanic soils is it more the nitrogen which is the limiting factor.

We have been discussing the rice yields of Tapanoeli and Sumatra's West Coast more fully than for any other preceding region or island, because in these regions rice agriculture is an old, developed, intensive culture closely adapted to the possibilities which the soil and climate afford. We have seen the great soil differences express themselves in great differences in productivity. The long narrow valleys from which one can see neither the Indian Ocean nor the Java Sea nor the low plain of the east coast, and consequently have a relatively less wet climate, often because of their more lasting fertility surpass other localities.

Into such lands Occidental science and culture now penetrate and prove that in one place the limiting factor is a lack of water, at least an uncertainty of irrigation, in another a lack of nitrogen, and almost everywhere a lack of P. At the same time, science points out how these deficiencies are to be remedied. As farmers the natives excel many other peoples of the Archipelago, and readily accept new ideas, and so without excessive optimism we may expect in the next few decades considerable progress in methods of cultivation, irrigation, fertilization, seed selection, etc.

* * * * *

Besides rice and other food crops, these districts have considerable areas of a number of plantation crops. For Tapanoeli these are especially coffee and rubber. Sumatra's West Coast grows cocos for the copra, and also tea and quinine.

The coffee culture in these regions was begun with arabica coffee and then much later robusta was brought in. By nature arabica coffee is not at home in the Netherlands Indies, and according to its ecological requirements certainly not in West Sumatra mountains. The climate there is really much too moist and the supplying of the roots with food substances from the soil is presumably not intensive enough. Therefore the coffee plants are set out in tropical high forest land, maturing in a few years, with good production in the 4th to 8th years. Then follow a couple of years decline, and then the plantation fails. The planter must begin anew elsewhere. So it was in the Padang Uplands, later it was the same and is still so in Mandailing, and it has been the same already for some years in the Dairi Lands. Veth[173] drew a characteristic picture, how in Mandailing, close to the equator, the forest coffee of the natives looked like high trees, with thin branches, few leaves, few berries, but--fancy quality! Meanwhile--one must wait not 10 years, but 20, before starting to use that same land again for a second planting. This reminds us of the Deli tobacco culture. But there the total time for a rotation is only 8 to 10 years, while here for the coffee, according to rough estimates, 30 years or even more are needed before first class forest is again ready to clear and burn. Actually that never comes about, since the natives do not leave the land alone but use it for cattle pastures, burn it off, etc., hence the abandoned coffee gardens do not grow up into forest but become cogonals. On the part of the Government,[174] endeavors are now being made to rescue the soil by the timely application of green manuring (with Crotalaria and Calopogonium) and to make it again suitable for the cultivation of coffee. But we will first have to wait to see whether or not the results will be successful. The cultivation of coffee makes certain demands of the soil and climate which are very difficult to satisfy through a long period of time. This is what makes coffee such an unstable crop and liable to disappear, especially when one thinks in terms of 50 or 100 years. Brazil is a large country and coffee is grown today in very different localities than it was 50 years ago.[175] On Sumatra and in other districts of the

173. R. J. Veth, Sumatra coffees of today, Tea and Coffee Jl. (May, 1933), p. 408.

174. B. J. Hagreis, and H. Vonk, Inh. Landb. Tapanoeli, Landbouw III (1927-'28), pp. 694, 704-705.

175. In a recent propaganda publication from Brazil it is stated that "at present in Brazil 200,000,000 coffee trees have been abandoned!" Compare also: Geograph. Rev. (New York), 22 (1932), p. 227.

Netherlands Indies the case is similar and for the same reasons.

It was but a few years ago that a great highway first opened up the Dairi lands, so that produce can now be transported out much easier and cheaper. Hence the area under coffee is still increasing. In Mandailing, however, the peak has probably already been passed--though there would seem to be a chance that through green manuring and reforestation sufficiently good new coffee lands could be built up. Regarding the coffee estates on the Goenoeng Talang we read[176] that around 35 years ago young plantings in the 5th to 7th year produced in one year 7 to 9, and even 10 quintals per hectare, but 20 year old plantings and those older produced only 5 qu./ha. In the good years another estate yielded even as much as 9 to 10 qu. /ha.--The soil was called "very crumbly and porous" and judged to be much better than that on older lands on other estates, with "more clay" but also with "more humus," which produced but 5 qu./ha. But now let us see the history from then on. After 5 years quite a bit of cassia stood next to the coffee; after 10 years the coffee was on the deline, and was replaced in part by cinchona. After 20 years the coffee was almost nothing and the cinchona had become the principal culture. After 30 years all the coffee was grubbed out, also the cassia, and following the cinchona they had begun to raise tea.[177]

This temporary character of coffee culture is apparently also the reason why Huitema wrote[178] as follows in his monograph: "Accurate data regarding the production of native coffee cannot be given." "There never is obtained a constant yield on any one planting, and thus in order to arrive at an evaluation of the soil from the production it would be necessary to collect very exhaustive statistics consecutively for many years. That is, however, not worth while for a crop such as this which lasts for but one generation. We must thus fall back upon estimates. Worthy of record is the following statement by Tergast[179] relating to Sumatra's West Coast. "The yields are dependent upon the quality of the land and upon the more or less successful maintenance of this quality The best yields are obtained in the regions around Fort van der Capellen (on the slopes of the Merapi volcano), in Korintji and Moeara Laboeh." (Around the Peik van Korintji; thus, in general, on the young volcanic mountain slopes).

* * * * *

While these remarks apply especiall to arabica coffee in the lower land, robust coffee is also planted out on a large scale in European plantation style on the foot of the Goenoeng Ophir at an elevation of 150 to 400 m. The Ophir is a volcano which has not yet been carefully studied. Its rock is perhaps somewhat on the acid side, dacitic. There is not a thick layer of forest humus on these lands. Moreover the soil in general is still on the sandy side, very juvenile. The light, primary formation of tuff[180] is still quite a little ways below the surface. Such a cemented layer may indeed be a hindrance to cultivation, yet it does not seem to be a hindrance to crops, as frequent experiences on Java, and also on Sumatra indicate. Apart from that the cultivation of robusta coffee is in the hands of the native population.

* * * * *

More important is the cultivation of tea and cinchona, here mentioned in the same breath, since they repeatedly occur together, with the tea most times at a lower elevation, the cinchona[181] higher up.

The oldest tea plantings on Sumatra

176. See: W. L. van Warmeloo, "De Nieuwe Gids," (Ned.-Indië), III (1901), p. 788.
177. The details of these changes are to be found in the full series of Handb. v. Cult. en Hand. Ondern. (Amsterdam, 1888, to the present).
178. W. K. Huitema, Bevolk. koffiecult. Sumatra, Diss. Wageningen (1935), p. 159 and also p. 170.
179. G. C. W. Chr. Tergast, Monogr. bev. koffiecult. Ned.-Indië, Med. Afd. Landb., 15 (1930), p. 24.
180. See pp. 143-144.
181. In the most recent years (1936) a considerable area of cinchona plantings seems to have been given up

are found on Tanang Taloe, north from the Ophir, a large portion on Precarboniferous rock. Even though the soil does possess residual fragments of young volcanic nature, on the whole it is a quite senile weathering product of the underlying clay slates. Evidently an old brownish yellow lixivium soil, which now and then has been somewhat rejuvenated by some volcanic ash. In its 25 years' existence this Estate has, indeed, known many ups and downs. This is no wonder, for those who understand know that tea grows best when tropical high forest land with adequate humus can be cleared for it. But when this surface soil has been eroded, then the subsoil is miserable and poor. The difference comes out in one single figure, the phosphorus content. In the but 5 cm. thick surface soil there is 0.219% P_2O_5 while at 30 cm. depth in the yellow lixivium only 0.008%. With such data at hand it is understandable that especially in the West Sumatra mountains there should be a change in forest clearing practice, so that immediately after the cutting of the forest nothing should be burned. I would also be inclined to advise that the soil should be quite thoroughly mixed to about one foot deep, so that nothing of that expensive thin surface layer should be lost. And then all the cut timber should be laid across the slope for the protection of the soil against erosion. In this way terraces would gradually form by themselves.

On Mt. (Goenoeng) Sago, which is also called Mt. (Goenoeng) Malintang, there lies an estate which plants not only tea but also cinchona. The rainfall is less than the average 5 to 6 meters on Tanang Taloe. But G. Sago has lain dormant quite a long time and the soil is also quite senile, more a reddish brown lixivium, here and there with some ash from Mt. Merapi. The so-called "mountain granulation" makes the physical condition of this plantation soil especially good.

At present on the Merapi there is also but one Estate raising cinchona. Not that on the fertile slopes of Mts. Sago and Merapi more estates should have been laid out, but the increasingly dense population below the existing forest reserves has taken up practically all the available and not too rough land for their agricultural purposes. The excellent sandy silt soils are ideal for cultivation and hold adequate moisture for cultivated crops.

Mt. Singgalang is less in demand. According to Kemmerling (see page 495), whose findings are confirmed by my own impression, this mountain is built up of somewhat more acid material, poorer in iron, and also more senile. The soil is thus less pervious, is paler, and more acid in reaction. Mt. Talang is better, and there are a number of estates on it. Along with the disappearance of the original tropical high forest humus, the old <u>arabica</u> coffee has passed out. The kind of cinchona which is being cultivated at present frequently cannot attain deep root development, since the surface soil reacts more acid than the subsoil, with the consequence that the constituents dissolving in the water in the surface horizons precipitate again down deeper in the soil. This has brought about a cementing, although it may be slight, into tuff or the formation of masses of iron oxides.

At present the most important tea and chinchona estates[182] lie on the northern slopes of the complex of young volcanoes to which the Piek of Korintji belongs. In comparison with other cultivated regions of this part of Sumatra, this soil has been cleared only a short time (see Fig. 190, page 510), so that the greater part was virgin land for these plantation crops.

Yet presumably these lands were not particularly rich in humus. After but a few years of cultivation some already began to show clearly the need of green manuring and N fertilization. What, however, indeed does strike one is that the absorptive weathering complex is by no means saturated with bases and shows an especially low content of absorbed calcium, besides a high though a less to be desired

182. With respect to the European estates on Sumatra's West Coast and their soil characteristics, there have been made accessible to me extensive reports and analytical data, which have not been published by the Extension Service of the Central Experiment Station Association at Padang. For this courtesy a special word of thanks is certainly in order. I am indeed grateful that I have been allowed to use this material.

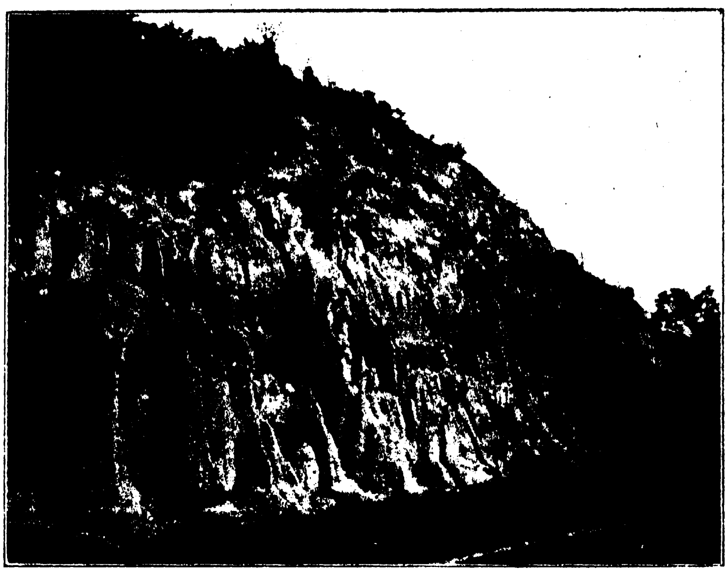

Photo by H. Witkamp

Fig. 190. Road cut through loose, pale tuffs near Sanggaran Agoeng, Korintji. Severe gully erosion. The surface soil above is held in place by humus.

content of sodium. The "clay"--if one may use this short word for the absorption complex--is thus not the "hydrogen clay" of the very strongly leached out senile soils, but rather a "hydrogen-sodium clay" with small quantities of potassium and magnesium, besides variable but relatively too small quantities of calcium.

More frequently on Sumatra there seems to be relatively too much Na and too little Ca in the absorption complex. Among other places this is the case in the Pakpak Lands, on liparitic soil, here and there on the East Coast, and also on the Ophir. It reminds us also of the lands which originated from acid pumice stone tuffs and dacites. In the following chapter, in the discussion of the rocks of the Djambi mountains, we shall again return to this point.

Meanwhile, if it turns out that the ejecta of the volcanoes of the Piek van Korintji complex have not been after all so very basic andesites with high calcium content, but rocks richer in sodium, then that would explain much. It would also incline us to the conclusion that besides extensive application of green manures and N fertilization, liming is necessary on many soils for the benefit even of the tea and cinchona plantings.

Of the rubber cultivation there is not much which can be said here, at least nothing leading to particular conclusions relating to the soil. In Mandailang there have been plantings of native rubber since 1910. These are among the oldest in the Netherlands Indies.[183] The reason for this is to be sought for in economic circumstances, but in passing it is worthy of note that the preeminently fertile portions of Java, Bali, Lombok, Celebes, Atjeh, Sumatra's West Coast, and the south of the Lampongs, produce little or no native rubber. There the inhabitants make a good living from the cultivation of food and other crops which they have raised since olden times. In those regions they did not and do not need to plant rubber to add to their income.

183. Hagreis and Vonk, l. c.

Regarding the export of native rubber, data from Luytjes[184] for the year 1925, calculated as percentage of the total, in combination with the regional quota, fixed in August, 1936[185] gave the following figures (Table 107):

In Djambi's low hilly country (cf. pages 541-546) there is nothing else but poor land. In consequence rubber has been a notable product. In Palembang's lower lands conditions were much the same. The "talang" is properly the undulating hilly plain, stretching out from the Lampongs over Palembang and Djambi to Indragiri and even to Bengkalis and to Laboeanbilik--the great, miserable terrain, of which the best, or speaking more correctly, the least bad pieces are planted to rubber. This has been maintained, even after rubber prices fell.

Table 107

PERCENTAGES OF RUBBER PRODUCED BY NATIVES IN THE SEVERAL DISTRICTS

	1925	1936
1. Western Subdivision of Borneo	20.4 %	21.1 %
2. Southern and Eastern Subdivision of Borneo	19.0 %	19.4 %
3. Djambi	18.4 %	15.6 %
4. Palembang	14.4 %	14.2 %
5. Sumatra's East Coast and Atjeh (especially Bengkalis and Upper Laboeanbilik)	13.4 %	12.9 %
6. Riouw and Dependencies, (especially Indragiri)	8.4 %	8.6 %
7. Tapanoeli	3.8 %	3.9 %
8. Sumatra's West Coast	2.1 %	2.9 %
9. Bangka	---	1.5 %
10. Bengkoelen, Lampongs	---	---
	99.9 %	100.1 %

In these figures (Table 107), which in the course of a decade obviously remain very uniform, we can see at once where in the Netherlands Indies the native rubber is grown, and where not. In connection with the soil of these rubber regions the following may be said:

In the western subdivision of Borneo (cf. page 402), except in the coastal strip planted with cocos, no very rich soil types are to be found. There are not even any active volcanoes there, just as there are none in the Southern and Eastern Subdivisions of that island. In the Eastern Subdivision there was and indeed still is rice cultivation (see pages 395-400), but the yields are not high[186] and in the time of high rubber prices the Malays, a trading people, quickly planted much rubber. Only after the fall of prices were the Hevea plantings in a number of places again replaced by rice.

"In Tapanoeli most of the native rubber cultivation extends along the highways between Sibolga and Padang Sidempoean, with Batang Toroe as the center. Kota Nopan is also a center, but of second rank."[187] Here the natives have thus given the preference to soils which were not good enough for other crops but which receive from the Batang Toroe, and other rivers from the North and east, older and younger volcanic material from the Loeboek Raja and its back country. In comparison with these soils, the surroundings of Kota Nopan, apart from the valleys which are regularly

184. These data have been taken from de Bevolkingsrubbercultuur in Ned.-Indië, in 7 Reports 1925-1927. A. Luytjes, VII. Final Report, p. 6.

185. See: Kolon. Tijdschr, 24 (Nov. 1936), 642.

186. Average about 17 quintals per hectare dry paddy, according to H. J. Schophuys, Diss. Wageningen. (1936), p. 138.

187. Bev. rub. cult. in N.-I., V. Tapanoeli en Sum. W. kust (1926), p. 32.

planted to food crops, are certainly of a still lower quality.

Finally an eloquent citation:[188] "The native rubber culture of the West Coast of Sumatra is not of particular significance nor will it ever be so--seeing that the Menangka farmer, who with his.... paddies and coconut culture....gets along well, and is not much interested in....the cultivation of rubber."--The few stretches where there is still enough rubber to justify mention are: (1) Loeboek Sikaping, subdistrict Mapa Toenggal, where "rubber may be planted only on poor, yellow, sandy lands, not suited for paddy or coffee. Red or black soils are "reserved" for the latter cultures[189]; and (2) the subdivisions Bangkinang and Pangkalan Kotabaroe, already belonging to the lower land and therewith geographically to Indragiri, Djambi, etc.--

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The planting of rubber is as new as the <u>coconut</u> culture is old. This latter is generally spread out along the west Coast of Sumatra, except on those places where the mountains descend precipitiously into the sea. Yet there is a difference. There are places where cocos crowd out everything else; and other places where there are only a few scattering palms. But in the interior the differences are still greater. In some places there are many cocos, in others none at all.

Searching for an explanation for this, we may safely proceed from the hypothesis that without doubt the natives must certainly have tried to grow cocos everywhere, so that the present day utilization of the land undoubtedly to a great degree is the resultant of the natural factors. After the earlier parts of this book appeared, the Chief of the Coconut Experiment Station at Menado, Celebes in a brief survey wrote me in part as follows:[190] "The lands which in the eastern part of the Archipelago are considered to be adapted to the cultivation of coconuts ordinarily are always on the coast. Here is the most important requirement for good development, namely, much water,..... Only in a few places in the interior is the cultivation of cocos possible on a large scale and indeed just in those places where in some other way the great water requirement of the tree has been met." (Abundant and uniform rainfall, a location surrounded by paddies, a quite high water table). This might be correct for Minahasa and for quite an extensive region around it, but for other parts of the Archipelago as, for example, on Sumatra the predominant requirement for cocos is certainly not the water, but rather, other factors which turn the balance. In Tapanoeli and Sumatra's West Coast there are hardly to be found any places with a continuous deficiency of soil moisture, and those localities with even a periodic lack of water are relatively very few, while it is still very much of a question whether or not those are the worst lands for the cocos. Yet on the other hand there are extensive bodies of soils, both at high as well as at low elevations, with an excess of rain and soil water, where the cocos simply do not grow at all and even if they do grow, they do not bear any nuts. Thus the soil there must lack something which hinders growth and nut production. On the coast, however, that factor, be it positive or negative, is not present, for along the coast if only there is the required supply of water the cocos always grow. "The cocos must hear the sea murmur," is the common saying of the people. But: "As to a favorable action of salt we have never come across anything," says Tammes.[191] That may be correct for sodium chloride. Sea water, however, is more than a solution of NaCl. It contains also K, Ca, Mg, SO_4 as well as Br, I, and minute quantities of a number of other elements, which may be the very ones of essential importance. If now somewhere in the interior these are lacking in the soil then that may be the reason why the cocos do

188. <u>Idem.</u>, p. 57.
189. Bevolk. rub. cult. in Ned.-Indië, V, p. 61.
190. P. M. L. Tammes, "De groeivoorwaarden en productie van de klapper," (Juli 1935), Not yet published (1937).
191. In an appendix of October, 1935.

not succeed, for likely the coco needs them, as our human body has need of traces of iron, copper, boron, manganese, and molybdenum.[192] So something similar might well also be the case with the cocos and if the lands on which they stand, lying higher, "hear the murmur of the sea" then there is a pretty good chance that on-shore winds can carry spray there from the sea and thus there is brought to the cocos what they have need of, which is much more than merely some cooking salt. But if the soil itself possesses the requirements for growth, then the proximity and influence of the sea is not necessary. This last for example is very probably the case on the volcanic terrains near to Pajakombo and Fort van der Capellen.[193] Smits says clearly "that in the stretches observed (Priaman, Pajakombo and Fort van der Capellen) the proximity of the sea has no effect upon the yield of nuts."

Variations in the rainfall within the limits which occur here (6,000-1,600 mm.) also seem to have no effect, nor do the variations in elevation between sea level and 500 m. But the soil structure is quite another matter. "It appears to be quite certain that nothing is so injurious in the cultivation of cocos as an impermeable or difficultly pervious soil. Also, if solid layers occur in the soil, then the soil pores easily fill up with silt, and the yield of nuts is noticeably less." As a "first requirement," Smits states "the most important are sand and good drainage." Further on (p. 11) he calls attention to this! "that the coco palm requires very good soil aeration. For growth and production strong root breathing is a primary factor. In the second place is the need of a supply of easily taken up plant nutrient materials."

Nowhere else are all these requirements so excellently fulfilled as on the large tuff plateau of Loeboek Basoeng lying behind Priaman and farther up on the foot of the Merapi. On the first mentioned terrain the soil is juvenile, sandy, rich in pumice stone gravel. The water conditions are thus extremely favorable. On the foot of the Merapi it is the same with very juvenile andesitic ash layers associated with adequate and satisfactorily moveable soil moisture. No wonder that cocos produce 60 to 70 nuts per tree per year. The humus content, however, is a bit too low. With green manuring and cultivation of the land the production may easily be raised to above 100 nuts per year.[194]

On the granite the soils also appear very useful, but they are poor in humus and the production is about 40 to 50 nuts. A similar yield is obtained on the small strip of coarse coastal sand. If on the last-mentioned strip the humus content is increased, the production can be doubled.[195]

The low lands, mostly alluvial, which lie behind the coastal sand are heavier, although in Priaman they are not heavy enough to be called a clay. Yet the yields are lower, say from 30 to 50 nuts. On the coral islands, however, only about 30 nuts, and on quartz sandy soil (on Tertiary rocks) mixed with schists, not even 15. These quartz sandy soils are the very ones which respond the best to humus and fertilizing. With these materials the productivity may be increased very considerably.[196]

This study by Smits thus illustrates excellently the influence of the parent rock, and at the same time the influence of the physical condition of the soil which

192. Compare pp. 475-477 of this book.

193. See: M. B. Smits, Onderz. Klappercult, Sum.-W. kust, Meded. Lb. Voorl. dienst 1 (1918), p. 6.

194. Smits, l. c., pp. 9, 28.

195. Smits, l. c., pp. 15, 28.

196. In Thailand (Siam) on poor sandy soils cocos often do poorly, at times bearing practically no nuts. But even if hundreds of kilometers from the sea coast the cocos yield quite well when growing close about the farmers' or laborers' dwellings or huts. In such locations the palms receive a sufficiently abundant and varied supply of plant food and water from the habitation wastes to grow well and bear good crops of nuts. (This appears to be the case whether the climate is continuously rainy, or has a long annual dry season.) Undoubtedly this is the explanation of another rather common saying about cocos, that "if they cannot hear the sea, they thrive only within the sound of the human voice." --RLP.

has been produced by the weathering of that rock, upon the success of coconut cultivation. How we do wish that the literature were rich in such monographs!

Of the rest of the crops of Tapanoeli and Sumatra's West Coast, tobacco is the one about which something should be said in connection with the soil. Around Pajakombo this crop finds the soil suited to it,[197] especially as expressed in the moisture conditions and the relatively easy provision of plant food materials. But not all places in and around the West Sumatra mountains, where there are similar young, sandy or light loamy ash lands, are equally suitable. The outer slopes toward the Indian ocean, Loeboek Basoeng for example, cannot be considered for tobacco, 1st because of the high rainfall, and 2nd on account of the salt water spray blown in with the strong onshore winds. In this way significant quantities of NaCl are brought onto the soil, thus unfavorably affecting the burning quality of the resulting tobacco.

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5. THE MOUNTAINS OF SOUTHERN SUMATRA

In spite of all their differences, the mountains of Djambi, Palembang, Bengkoelen and the Lampongs show from the point of view of soil science so many points of similarity that it seems to be desirable to here discuss this part of Sumatra as a whole.[198] Then, likewise, the whole low plain of the East coast can be treated as a whole.

Soil-Forming Rocks

The most important contrast between the mountains of Southern Sumatra and those of the central and northern part of the island is that in Southern Sumatra in the late Tertiary and especially in the Quaternary, volcanic activity played such a predominant role that, except for a few Pretertiary complexes remaining, but very small areas of those older rocks now lie on the surface in a way to have any effect in a soil-forming capacity. Those Pretertiary complexes are:

1. The Tigapoeloe mountains, lying half in Indragiri and half in Djambi. Just as is true of the similar northerly lying mountains, a large part of this complex is composed of "sandy clay slates and quartzitic sandstones, here and there altered into hornblende and nodular slate."[199]

2. The complex between the Batang Tebo and the Batang Merangin, made up not only of granite, but of all sorts of very old volcanic material, old tuffs and fossil lahars.[200] But here we do not find the quartz sandstones and clay slates which are so very widely distributed farther north.

3. The complex between the Batang Tembesi and the Ajer Rawas and Ajer Roepit, which agrees with the "Trias region" to the southwest mentioned under (2). The rocks of this complex are slates with phyllite-like shining surfaces, a few quartzite-like sandstones, lime phyllites and limestone masses."[201]

4. The Goemai mountains in Palembang are again different and show inclusions between "more or less silicious clay slates, with porphyrite and porphyritic

197. With respect to this compare what has been said more at length on pp. 474-5, 484-5, 488 ff. of this book.

198. In another publication I have already done this: J. W. J. Wellan, Zuid-Sumatra, Wageningen, (1932), pp. 71-81.

199. J. Zwierzychi, Toel. bl. VIII: Geol overz. k. N. I. Arch., Jb. Mijnw. (1929), p. 89. It is logical to suppose that under these there are hidden "sandy clay slates" and "loam slates"; but that word "loam slates" is still not yet generally in use among geologists. But if the main mass of the rock is made up of quartz grains of a size between 20 mu to 2 or 1 mu, it is difficult to correctly call it a sandstone and just as difficult to call it a clay slate, even though the rock possesses about 10% clay or even still somewhat more.

200. J. Zwierzycki, l. c., pp. 82-83.

201. J. Zwierzycki, l. c., p. 86.

tuffs; thus old volcanic materials which are also found in the 3rd complex.

5. The Boekit Garbo, between Batoeradja, Martapoera and Goenoengtoewa, with granite and tuffs as under (4) but also sedimentary rocks, in part metamorphically altered, as mentioned[202] under (3) and (1) above.

6. Finally, in the Lampongs a complex of an entirely different nature, consisting not only of granites and granodiorites varying to quartz diorites, but also of crystalline schists, which include gneisses, amphibolite, biotite gneiss, chlorite schists, mica quartzites, amphibole schists and marble. Thus forms are included which are both very rich in quartz and very poor in quartz, or some without any quartz at all.

* * * * *

This is practically all that is to be said about Pretertiary rocks. To the Tertiary belongs the Paleogenic, which while very important in central and northern Sumatra, does not occur in southern Sumatra in bodies of any extent except a single long, small, and several times interrupted strip of the upland from Tais, via Tandjong Sakti, approximately to Ranau lake. Again fine distinctions as to geologic age, for example, what Tobler calls Eocene, and Zwierzycki Paleogene, the new geological map of Sumatra shows as Old Neogene or, in short Batoeradja layers,--are really unimportant for our purposes, since we are especially concerned with the petrographic differentiation. In general we are in agreement that clearly from the beginning of the Tertiary the volcanic activity continued to occur at a continually increasing rate. This makes it obvious that because of the frequent and many different kinds of eruptions which have occurred in South Sumatra, the earlier geologically the land surface, the more it has been covered over and obscured from view.

The ejecta which resulted from the volcanic activity from the beginning of the Tertiary (really quite a little earlier, but after what has just been said about such minor differences, mention here of small differences is no longer in order!) down to today have been, in general, drawn off by turns first from one of two reservoirs and then from the other. That is, at one time the magma was acid, then at another time magma of intermediate composition came to the surface of the earth. The existence of definitely basic magma has been established in only a few places. It is further to be noted that taken by and large the richness of the magma in dissolved gas, and the pressure of it at the instant of the eruption apparently was greater, as the magma was more acid. As a rule the acid magma which reached the surface was completely exploded to pumice stone and ash, which in one single terrific explosion had been thrown up into the air, and then spread over a great area, to settle down upon the earth. Very basic magma, on the other hand such as the basaltic, time and again flowed out relatively quietly as lava. The intermediate magma showed an intermediate character. This has given both explosivly thrown-out efflatas (especially in the beginning of eruptions) as well as lava, both porous and solid.

From this it follows that a greater proportion of the material of volcanoes, originating through gradual building up, must consist of intermediate and basic rocks (andesite, and basalt) although acid ash and pumice stone layers also occur in them. But for the acid eruptions a single definite eruption point can seldom be found. Rather a series of points have many times been located along a long fissure or a series of cracks as at Toba lake, Ranau lake, etc., and the efflatas lie scattered far and wide over an area much greater than that covered by one even very large volcano. These acid ash and pumice stone efflatas can give rise to soil types at a great distance from the eruption point. By contrast the basic eruptives are in the first instance tied to the point of eruption and give rise to the soil types derived from these basic rocks on the slopes and close around the base of the volcanoes from which the magmas came.

202. R. W. van Bemmelen, Explanation accompanying sheet 10 of the nieuwe Geol. krt. Sumatra (1932).

"In the first instance" should certainly be emphasized, because water flowing off over the surface transporting volcanic products may sooner or later enormously extend the area over which they are spread.

This more general consideration is necessary in order to be able to clearly understand the primary distribution of volcanic parent rocks in Southern Sumatra. Furthermore, it is also necessary to keep in mind that there is apparently a certain chronological succession:[203] first predominantly andesitic eruptions, now called "old andesites," in so far as they were erupted in the Old Neogene or Paleogene; then younger andesites and dacites; thereupon followed predominantly acid eruptions of liparitic material, that is to say, quartz dioritic to granitic in composition, giving rise to the "acid tuffs" which cover over almost the whole land; and thereafter finally a pronounced building up of young andesitic volcanoes. That does not deny that acid rocks were also formed in the older Neogene just as in the youngest Quaternary. On the other hand in the interim more basic magma was ejected. But on the whole, Nature held herself within the broad lines sketched, which for that matter are also true for the volcanic activity which has occurred throughout the Batak lands; and likewise also in the Padang Highlands. If all these features are not discernible it is probably because of erosion which has brought about a more or less heavy accumulation or removal of acid pumice stone where "old andesites" stick up through, or where local younger volcanoes have developed on the surface and have obscured the original succession.

If we should fly along above the mountains, from the Piek van Korintji southeast to the Lampongs, we would get the following picture:

1. Where at present stands the Piek van Korintji with its accompanying volcanoes Patah Sembilan, Boekit Boentak and especially the Goenoeng Toedjoeh, there was previously certainly a great expanse of acid ash and pumice stone, from which the rivers flowing out toward the northeast and then curving around toward the east had carried off, originally in the form of lahars, a great mass of material. In this way the plateau of Moeara Boengo was built up. In how far the latter activity of the great volcanoes is to be credited with this formation, cannot be said. In 1922 Tobler[204] put it well and briefly: "As to the lithological composition of the tuff and agglomerate cover (in the Barisan mountains of Djambi and surrounding regions) no closer studies have been made." And 8 years later Zwierzycki wrote[205] "Locally basaltic, dacitic and liparitic tuffs also occur, but in the literature consulted the statements are so vague and of such a local character that from them it is impossible to give on the map even provisionally the distribution of the different types."--In the south, thanks to the new geological survey of Sumatra, we are indeed much more fortunate.

Seeing that thus even today we still do not know what kind of rock or rocks, for example, compose the Piek van Korintji, and only by analogy suppose that the rocks are principally andesite[206] with just as much, or perhaps more correctly with just as little certainty we may suppose that the andesitic efflatas have apparently not penetrated far toward the northeast and east. Otherwise the plain of Moeara Boengo would indeed be more fertile and more densely inhabited than is at present the case.

2. The plain of Korintji, with the lake of the same name, has been described by Tobler[207] as a partially filled up lake, to the filling of which all the rivers to the northwest of it have contributed and as they daily continue to contribute to fill this lake. It is not impossible that the origin of this plain was similar to that of the Toba lake, and thus may have been the source of one or more awe-inspiring liparitic tuff eruptions. But the rock now filling up the plain seems to be of a less acid nature.

203. For details regarding this see the publications of R. W. van Bemmelen: Verh. Geol. Mijnb. Gen., Geol. Serie IX, 2e st. (1931), pp. 57-76, and: Nat. T. v. N. I. (1932).

204. A. Tobler, Djambi-verslag, Jb. Mijnw. (1919), Verh. III (1922), p. 354.

205. J. Zwierzycki, Toel. bij bl. VIII, Geol. Overz. kaart N. I. Arch., Jb. Mijnw. (1929), Verh. (1930), p. 109.

206. Figure 190 raises serious doubts regarding this.

207. Tobler, l. c., p. 357.

The small plain of Soengei Tenang, which possibly also in its time had been a lake now filled up is really an extension of the Korintji valley. These valleys are only partially separated by the higher land described under (3) below.

3. Between the two plains running in a northwest-southeast direction there lies the higher land of a series of volcanoes; first 3--the Goenoeng Raja; the Boekit Sebandar and the G. Koenjit; and then 4--the G. Soembing, the Bt. Oeloe Nilo, the Bt. Mesoerai and the Bt. Toengkat. Of those the Koenjit and the Soembing are perhaps not even yet entirely extinct. At least there is still solfataric activity.

The question as to what kind of rocks these volcanoes have erupted is difficult to answer. On one of the slopes of Soembing, Tobler[208] has observed blocks of andesitic rock, and also dacitic tuff. Most of the rivers which now rise on these volcanoes flow toward the northwest and unite with the Merangin and the Tembesi. Lower down along the last-mentioned rivers and in particular around the fertile forelands (renah lands) are found deposits which are used as paddies. But higher up, nearer to the foot of the volcanoes, thus in the terrain lying between the road connecting Moeara Siau and Djangkat and the lake of Korintji there are almost no deposits. From eye witnesses I learned that "that terrain was a plateau which sloped slightly toward the northeast and was cut into very deeply by valleys,--a region which reminded one of localities around the Toba lake, since it was also very sandy and rich in pumice stone and held so little water it was not even considered for cultivation, neither for plantation crops nor native agriculture." So we shall thus probably be not far from the truth if we accept that here lies a great expanse of liparitic tuff. But that does not necessarily also mean that the above-named volcano is built up of the same rock. This can very well be of a more intermediate composition and thus be dacitic or andesitic. But then it is also likely that these dacites and andesites are not spread out so far from the point of eruption. In other words, a larger proportion likely remains behind on the volcano and on its immediate surroundings. If these suppositions are correct, they should be able to explain why the fertility of the soil is boasted about in stretches lying nearby, such as the plain of Moeara Manderas, along the Soengei Mentenang, and likewise in the uppermost headwaters course of the Tembesi, just north from there.

4. Now to the southeast to about Ajerdingin there follows a piece of mountain land which is divided into two portions by the line which is the continuation of that of the plain from Korintji and which runs along the upper course of the Ajer Seblat, Tambang Sawah, Moeara Aman and the upper course of the Ajer Ketahoen toward Ajerdingin. Northeast of this line lies much old rock such as sandstones, clay slates, already mentioned above (page 514 under (3)) and, according to the map of Zwierzycki, also much old andesite and rhyolite. Whether this rhyolite differs in composition from that of the liparitic tuffs occurring in such quantities everywhere on Sumatra may be doubted. According to Moerman's description[209] it has precisely the same minerals in it, namely sanidine, ordinarily also much plagioclase, quartz and almost always biotite, while hornblende and augite are less frequent. The rhyolites are most times very rich in quartz, with a considerable content of plagioclase (then also richer in calcium). They grade into dacites, whereby at the same time the content of hornblende increases and the color becomes darker." We must not neglect to record the high content of volcanic glass, especially in the rhyolites. When the gases existing in it under high pressure suddenly escaped from this glass this material became the pale pumice stone. Perhaps where solid rhyolite exists, one might find the eruption points of the astonishingly great masses of efflatas of this composition in the lowland of Djambi, and perhaps these masses are to be conceived of as already degassed final residues of these eruptions.

Southwest of the above-mentioned line lying northwest of Moeara Aman there

208. Tobler, l. c., p. 434.

209. C. Moerman, Versl. verkenn. tocht in ged. d. resid. Benkoelen en Palembang, Jb. Mijnw. (1915), Verh. I, p. 89.

are still a number of mountains of "old andesites," but then there follows:--

5. Approximately at the elevation of Moeara Aman a region of younger volcanic activity, with the smaller Boekit Paboes, the Bt. Loemoet, the Bt. Gedang Oeloe Lais and the Bt. Beriti as a transition into a region of respectably large volcanoes, such as the Bt. Daoen and Oeloe Palik, which are also to be considered as already extinct; the Bt. Kelam seems to be still younger, and the Kaba must be counted as recent and active. These differences in age will be considered more closely when we discuss the soil types.

6. Southeast from the Kaba we again find relationships similar to those we have already met in Sumatra. The upper course of the Moesi and the Ajer Keroeh flow along the extension of the line Moeara Aman,--Ajerdingin--Tjoeroep. However, by the Kaba this line is bent out somewhat toward the southwest. Beyond Kepajang, again southwest from this line, we find "old" andesite, northeast from there with the Boekit Besar there begin the still older, already mentioned Goemai mountains (page 514 under (4)) with their silicious clay slates, most times with tuffaceous, old volcanic inclusions. Lying in between these two mountainous regions is again a young volcanic terrain with the Boekit Dingin and the Dempo. This last-mentioned volcano is still active and now dominates its surroundings, although in comparison with those of the many times mentioned terrible outbursts of more acid magma in former times, the Dempo's effusives, intermediate to basic in nature, are quite modest in extent. For that matter it is also very much a question whether the Dempo is really the eruption point from which have come the efflatas out of which the high plain of Pagaralam has been built up. Perhaps it once spread out excellent ash, which weathered to good land on which forest stood. But at present there is not much left of the forest. In a subsequent chapter something more will be said about this.

7. Southwest from the Dempo, in the southeasterly extension of the just-mentioned "old andesites" there is again some mountainous land with old granite (Boekit Pajoeng, Boekit Radja Mandara), and a Paleogene strip with Tandjong Sakti in the middle. Then crossing the old northwest-southeast line, we come back again onto very old crystalline schists. It is true that the area of these which is exposed is very small, but even so it reveals something of the basement rocks of Sumatra. It is indeed surprising that this exposure actually exists at all. For north and south of it are numerous points of volcanic eruption, although it is true these are no longer young.

8. Coming now into the surroundings of Ranau lake, we are within the region covered by the new recently published geolocial map.[210] The great advantage for us in this is the much greater detail by which the different rocks are shown, while in the descriptive legend on the maps are also a number of analyses, as well as many valuable references to the literature. Of this mention has already been made in the general introduction of Sumatra (see page 417). Here we may now elaborate the subject by recording a number of analyses of different rocks from one and the same intrusion which at the center is more acid and on the edges more intermediate in composition (see Table 108, page 519).

The first rock (83) represents the central part of the batholith. It shows the highest figures for SiO_2 and K_2O and the lowest for almost all other constituents. The following sample (69) has an especially high Na content with a low amount of K. No. 78, on the contrary, again has a minimum Na content. Thus the amount of Na in these rocks is not to be relied upon. The three first-mentioned rocks, which are acid, have clearly more SiO_2 but less Al_2O_3, Fe_2O_3, FeO, MnO, MgO, H_2O+, TiO_2 and P_2O_5 than the three last-mentioned which are of intermediate composition. Thus here TiO_2 and P_2O_5 clearly accompany the metal oxides, particularly the metasilicates of Fe and Mg.

210. Geol. kaart v. Sumatra 1:200,000, Blad 6, Kroeï (1933). Bewerkt door R. W. van Bemmelen.
Geol. kaart v. Sumatra 1:200,000, Blad. 3, Bengkoenat (1932) Bew. d. J. Westerveld.
Geol. kaart v. Sumatra 1:200,000, Blad 2, Kota Agoeng (1931), Bew. d. J. Zwierzycki.
Geol. kaart v. Sumatra 1:200,000, Blad 10, Batoeradja (1932), Bew. d. R. W. van Bemmelen.

Table 108

ANALYSES OF DIFFERENT ROCKS OF THE GREAT GRANITE BATHOLITH IN THE

BARISAN MOUNTAINS OF BENKOELEN[1]

Analyses by Djoko Joewong and J. P. den Haan

Original Sample No.	83	69	78	66	155-159	67
Kind of Rock	Biotite granite	Biotite granodiorite	Granodiorite-porphyrite	Quartz-diorite porphyrite	Quartz diorite[2]	Quartz diorite
Place Collected	W. Baroe piket 324	W. Bambang p. 202	W. Pintau p. 85	W. Bambang p. 16	2	W. Bambang p. 163
SiO_2	75.41	71.92	69.63	59.09	57.54	56.24
Al_2O_3	13.11	13.95	15.84	18.50	16.47	17.33
Fe_2O_3	0.33	0.66	0.64	1.73	4.45	3.07
FeO	1.29	2.48	2.04	5.12	3.37	6.21
MnO	0.02	0.06	0.02	0.12	0.09	0.12
MgO	0.37	0.61	1.21	1.45	2.91	3.53
CaO	1.28	3.65	6.21	7.69	6.85	7.42
Na_2O	3.20	4.05	2.28	2.91	3.14	3.44
K_2O	3.80	0.61	0.93	1.38	1.34	0.31
H_2O + ...	0.72	0.83	0.79	1.00	2.20	1.41
H_2O -	0.15	0.21	0.11	0.16	0.28	0.06
CO_2	0.11	0.29	----	trace	----	----
TiO_2	0.18	0.38	0.45	0.80	1.06	1.01
P_2O_5	0.05	0.06	0.06	0.10	0.14	0.11
S	0.05	0.36	----	0.03	0.13	0.04
Total	100.07	100.12	100.21	100.08	99.97	100.30

1. J. Westerveld, G. K. Sum., 3, Toel., pp. 26-29.
2. R. Van Bemmelen, G. K. Sum., 6, Toel., p. 28. Very probably a secondary intrusion to the north from the great batholith.

If we now consider the acid effusives of Southern Sumatra (see Table 109, page 520), then in composition these come quite close to the above-mentioned Nos. (83), (69) and (78). We may thus certainly conclude that they came from a similar magma; a magma which if it had not reached the surface of the earth, would have hardened to a granite or granodiorite of some sort or another.

Only the liparitic tuff from the Upper Palembang layers falls out of line because of extra much SiO_2, especially little Al_2O_3, etc. But regarding this, Van Bemmelen adds[211] "The quartz content has possibly been enriched secondarily as a result of river transport." Meanwhile the analysis is of especial value in that it permits a glimpse into the composition of these extensive Upper Palembang beds, and which in Southern Sumatra are an important factor in soil formation.

Otherwise the compositions are not notably divergent; Al_2O_3 12-15%, never but a trifle of MnO; Na_2O from 2.8-4.1%. Iron to 3%, but sometimes under 1%; MgO not above 1%, but sometimes almost entirely absent. Calcium is also small, sometimes

211. R. Van Bemmelen, G. K. Sum., 10, Toel., p. 30.

Table 109

ACID EFFUSIVES OF SOUTHERN SUMATRA[1]

Name	Liparitic tuff	Obsidian	Liparite block	Liparite block	Obsidian block from the tuff	Perlite	Pumice stone block	Perlitic Lava	Perlite bomb	Pumice stonelike dacite block
Place collected	Upper Palembang layers	Pg. Semoet	Pg. Semoet tuff West Pajoeng	Pg. Semoet tuff West Roembia	West Koeboe-tengah moedik No. 107	Goedong soerian depression No. 144	Ranau tuff No. III	W. Laboe-anloenik No. 110	West Antatai No. 112	Ranau tuff No. 105
Analysis from	Löhr[2]	Essenwein	den Haan	den Haan	den Haan	den Haan	den Haan	den Haan	den Haan	den Haan
SiO_2	82.19	75.52	75.50	75.50	73.70	73.56	72.56	70.05	69.36	67.61
Al_2O_3	8.31	12.32	13.22	12.25	12.79	11.94	14.09	14.94	14.91	15.49
Fe_2O_3	2.48	0.46	0.88	1.64	0.65	0.91	0.53	1.62	1.31	1.66
FeO		0.36	0.16	0.15	1.82	0.47	0.33	1.59	1.17	0.62
MnO		0.02	----	trace	0.01	0.06	0.02	0.05	0.04	0.02
MgO	0.12	0.17	0.02	0.09	0.28	0.04	0.14	0.98	0.91	0.36
CaO	0.14	0.95	0.85	1.34	1.63	1.27	1.71	3.26	2.70	1.68
Na_2O	3.42	2.97	3.27	3.67	3.83	3.67	2.78	4.12	3.78	2.97
K_2O	2.12	6.51	5.09	4.63	3.45	3.10	2.68	2.67	2.52	3.19
H_2O + ...	1.20	0.34	0.77	0.60	1.19	4.23	4.23	0.63	2.49	4.54
H_2O -		----	0.29	0.21	0.20	0.43	0.85	0.08	0.36	1.14
CO_2		----	----	n.b.	----	----	----	----	----	----
TiO_2		0.21	0.05	0.11	0.38	0.23	0.29	0.46	0.32	0.61
P_2O_5		0.37	0.03	0.04	0.08	0.07	0.16	0.10	0.24	0.03
S		----	----	----	----	----	----	----	----	----
Total	99.98	100.20	100.13	100.23	100.01	99.98	100.37	100.55	100.11	99.92

1. R. Van Bemmelen, l. c., 6, pp. 40-46, and 10, pp. 30, 34.
2. R. Löhr, Beitr. z. Petrogr. süd-Sumatra-Diss. Münster i/W, p. 42. Referred to by Van Bemmelen, l. c., p. 30.

under 1%. Potash on the contrary is from 2.5 to 6.5%. Phosphoric acid is very variable, sometimes almost lacking, but sometimes as much as 0.37%. Taken by and large, quantities of plant food substances are one-sided, in some respects low. In general the petrographic composition of these acid tuffs is very uniform. They consist of much white pumice stone, from large chunks to fine gravel, some of which is but slightly porous, in other cases foamy. In these tuffs are quartz and sanidine phenocrysts and locally more or less mica, and more or less material which inclines towards a dacitic composition. The Ranau tuff also contains plagioclase and some magnetite.

In the third place we may now consider a number of analyses of less acid rocks (Table 110, page 521). Of the so-called "old andesites" there are none at hand. The rocks analyzed are all young, even younger than the great mass of the above-recorded acid effusives. This is of importance since, where they do occur, be it then also in a much smaller area, these younger rocks cover over the acid tuffs and have displaced them in the soil-forming functions.

In contrast with the preceding acid

Table 110

ANALYSES OF YOUNGER, LESS ACID ROCKS

Name	Dacite	Hypersthene dacite	Augite hypersthene andesite	Pyroxene andesite	Amphibole pyroxene andesite	Pyroxene olivine basalt
Origin	West Koeboe-tengah moedik No. 106[1]	West Bambang No. 52[2]	South slope of the G. Seminoeng No. 104[3]	North slope of the G. Dempo[4]	Oemb. Mandah SW from the Bt. Bedil[4]	Oel. W. Djongkang NE Bt. Mapas[4]
Analysis from	den Haan	den Haan	den Haan	Roothaan	Roothaan	Roothaan
SiO_2	63.29	62.39	61.82	61.18	60.72	55.52
Al_2O_3	15.36	16.12	15.98	17.15	17.82	14.76
Fe_2O_3	4.16	2.06	3.01	1.62	5.82	3.10
FeO	1.58	3.23	3.17	3.67	0.58	4.68
MnO	0.10	0.10	0.07	0.03	0.09	0.10
MgO	2.71	2.42	2.56	2.07	1.35	6.96
CaO	5.19	5.14	4.99	7.22	5.72	9.55
Na_2O	3.49	2.53	3.73	3.30	3.83	2.43
K_2O	2.07	2.05	2.06	2.64	2.96	1.84
H_2O + ...	0.60	2.59	0.66	0.24	0.52	0.26
H_2O -	0.66	1.00	0.42	0.04	0.08	0.06
TiO_2	0.86	0.59	1.47	1.11	0.73	0.92
P_2O_5	0.10	0.09	0.14	0.11	0.08	0.15
Total	100.17	100.31	100.08	100.38	100.30	100.33

1. Van Bemmelen, l. c., 6, p. 40.
2. Westerveld, l. c., 3, p. 29.
3. Van Bemmelen, l. c., 6, p. 36.
4. H. Ph. Roothaan, Nat. Tijds, N. I., 89 (1929), pp. 507-510.

effusives, in these less acid rocks there is a much higher iron content, with which also more Ti is combined. But at the same time there is a higher content of the other metals Al, Mn, Mg, and Ca. The P content is not high, which is contrary to expectation, since as a rule, the more basic rocks (on Java, for example) also show quite high amounts of P.

9. Southeast and east from lake Ranau lies an extensive volcanic mountainous region. Here only very small bodies of sedimentary rocks are exposed at the surface. On a basement of here and there today again exposed "old andesites" there were, speaking in general terms, spread out in the young Neogene and Quaternary great masses of acid efflatas which subsequently were carried on out toward lower land by water, at times as lahars but more usually by the rivers. Thereafter effusives of intermediate and more basic composition broke through and themselves built up a great number of volcanoes. Then followed a single mighty explosion, the Ranau eruption of pale pumice stone and crystalline ash, of which we still now find remains on the volcanoes which before that eruption had already become dormant.

Also at approximately that same time, or even earlier, there must have occurred a similar great eruption somewhere north of Telok Betong.[212] In that region there are now small, steep, isolated little mountains, formed from a liparitic magma (see Table 111 for analyses of samples

212. Zwierzycki, l. c., 1, p. 19. Westerveld, l. c. 5, pp. 17 and 18.

from Goenoeng Koenjet and Goenoeng Kedaton).

And finally thereafter again less violent volcanoes erupted, such as the Seminoeng in the northwest, on lake Ranau; and in the south of the Lampongs the Tanggamoes, the Goenoeng Ratai and Goenoeng Begamoes, the Goenoeng Ratai and Goenoeng Betong and the most southeasterly, the Radjabasa; besides which a number of less important points of eruption may be mentioned. Since, in the explanations on pp. 1 to 6 of the Geological Map of Sumatra one can find given all the known particulars relating to this mountainous region it may thus be considered superfluous that anything about it be included here. Suffice it to point out that the foremost soil-forming rocks are acid tuffs and more intermediate and basic tuffs, as well as solid rocks. However, there were but few lava streams. The single body of solid rock of significant area is the so-called "island of Soekadana," a large quite flat cake of basaltic lava. Its composition is indeed a surprise in contrast with that shown by the analyses of the glass-like violet white rocks of the steep little hills, north and east of Tandjoeng Karang (see Table 111, page 523).

Except for one sample that is more andesitic in composition, the figures fall between those which are given here. Hence the five additional analyses of Soekadana basalt samples, carried out by Willems,[213] give no new points of view.

Relating to the crystalline schists, as well as especially to the sedimentary rocks of Southern Sumatra, I should liked to have seen added to Table 111 a few figures of analyses of such rocks. Perhaps they are not so very necessary, since for our purpose these rocks are of less importance, and of less extensive occurrence in the mountains of which we are here speaking. The analysis by Löhr (page 520) is actually the only one which is available. Thus far the geological mapping of south Sumatra has not given us a single new chemical analysis of a sedimentary rock!

Nor have quantitative mineralogical analyses yet been done, at least not yet published. Mention has been made "of quartz-rich and quartz-free tuff sandstones, claystones and marls"[214] but without any indication as to how much quartz these rocks really do contain. Also mentioned are "tuffaceous calcareous marls and tuffaceous limestones"[215] but without any data as to how much Ca, how much tuff material, or how much clay is in them. This is true in part of land sediments, and in part of marine sediments; as to the content of Fe, Mn, Mg, Ca, Na, K and P in the two groups of rocks, we still know nothing at all. And yet no one would deny that data of the sort here referred to as lacking are, apart from their geological significance, of great value from the soil science standpoint. Hence it is most strongly to be hoped that as the geological mapping of Sumatra proceeds from the south toward the north, and therewith also as the areas of sedimentary rocks increase in proportion to those of neighboring volcanic formations, more attention will be devoted to the analysis of sedimentary rocks.

It gives us hope that a few years ago[216] Esenwein made a beginning in the systematic petrographic study of sediments of different strata in the Palembang formation. From this study we were surprised to learn that the cementing material of most of the tuff rocks investigated from the Upper Palembang layers "is characterized by the presence of a notable, secondarily-formed, strongly pleochroic clay mineral"[217]; an aggregate of mica-like, leaf-shaped, curved and bent little flakes. Now it is becoming more and more evident as to how much importance for such soil characteristics as absorption and plant nutrients are the differences between the diverse clay minerals.[218] Now we ask: what can that Palembang mineral be? Beidellite or montmorillonite or what else? The answer will have great pedological and agricultural importance. Whatever the answer to this may be, a beginning has been made toward solving this problem and we may

213. See: Jb. Mijnw. (1931), Algem. Ged., pp. 187 and 191.
214. L. c., 2, p. 14.
215. L. c., 3, p. 17; cf. also: 5, pp. 12-15; 6, pp. 12-24; 10, pp. 9-31.
216. Kort Versl. Dienst v/d Mijnb. 2e Kwart (1932), pp. 24-25, Jb. Mijnw. (1932-33), pp. 89-90 (1935).
217. See also: K. A. F. R. Musper, Geol. k. v. Sum., Toel. bl. 15 (1933), p. 25.
218. See: pp. 77-78.

Table 111

ANALYSES OF IGNEOUS ROCKS FROM SOUTHERN SUMATRA

	Glassy Liparite Lamponga		(Plateau?) basalt from Soekadana Lamponga		
Origin	G. Koenjet	G. Kedaton	G. Tiga	--	--
Number	119	127	24	26	31
Analysis by	Willems	Willems	Willems	Willems	Willems
SiO_2	74.54	73.99	53.28	50.13	51.42
Al_2O_3	14.39	15.22	16.19	16.27	16.04
Fe_2O_3	0.99	0.56	3.01	2.39	2.55
FeO	0.31	0.18	5.42	7.38	6.42
MnO	0.04	0.03	0.12	0.13	0.12
MgO	0.05	0.09	6.58	8.57	8.23
CaO	0.77	0.45	8.49	8.30	8.36
Na_2O	4.10	3.48	3.64	3.43	3.47
K_2O	3.56	3.49	1.23	1.08	1.28
H_2O + ...	1.03	1.79	0.51	0.57	0.54
H_2O -	0.37	0.85	0.19	0.28	0.29
TiO_2	0.14	0.15	1.54	1.45	1.45
P_2O_5	0.01	0.01	0.25	0.13	0.14
CO_2	trace	trace	----	----	----
Cr_2O_3	----	----	0.02	0.03	0.04
Total	100.30	100.33	100.47	100.14	100.35

anticipate that the publication of that study will stimulate yet more important studies, especially if quantitative estimates of the constituents can be obtained,[219] as well as separate analyses of the minerals by themselves.

Climate

In continuation of what has already been said (pages 420-426) about the climate of the Southern Sumatran mountains we may summarize our knowledge briefly as follows:

For the greater part it is continually humid, especially along the west coast up to the summit of the Barisan Mountains; but also on the east side where high mountainous land gradually rises up above the plain. In between, there are long narrow valleys with very much less rainfall, such as Padang Gelai shows for example. But even a place such as Kedongdong, with not even 1,600 mm. per year, has no single month with an average of less than 60 mm. and Soengeipenoeh with a total of not as much as 2,000 mm. has no single month with less than 100 mm. Theoretically the possibility is not excluded that a few spots could be found with a rainfall of about 1,500 mm. per year and a couple of arid months. But in view of the continuously humid character of the whole region, that does not seem likely.

The elevation varies between about 500 and about 3,000 m. and the average temperature varies between about 22°C and about 6°C. Consequently the soil temperature varies between about 25° on deforested, relatively low-lying terrain and about 5° on the slopes of the highest peaks which are bare and exposed only to ascending winds. The observation that beard-like moss occurs on the high trees of the Sumatra mountain regions even frequently as

219. Cf.: P. Esenwein, Wetensch. Meded., 24, Dienst v/d Mijnb. (1933), pp. 92-99.

low as about 700 m. elevation, while on Java it is seldom found lower than 1,000 m. indicates how chilly the climate is on these Sumatran mountains. In the long narrow valleys and on the plateaus, as in Korintji, on Tjoeroep, in the Semendo, around lake Ranau, and in the Way Lima, it is drier, sunnier, and warmer than at points of equal elevation lying on the outer slopes, facing the Indian Ocean.

Ways in Which Weathering Takes Place and the Resulting Soil Types

In so far as it relates to the differences of the rocks, there are big differences in the ways in which weathering takes place and soil forms in the mountains of Southern Sumatra. Yet with respect to the climate the differences are relatively small, especially if we take into consideration the extent of the region we are considering. Consequently, by discussing weathering according to the parent rocks is the best way to get a general idea of the weathering and soils.

In the preceding section we have already seen how the parent rocks first became exposed and were weathered in part in compact form, and in part in a finely divided form. From this it is evident that we really ought to consider two different series of weathering forms, although as a result of the mechanical grinding up on the surface of compact rocks, there also have been intermediate forms.

(1) There normally developed on the granite massives a grayish brown and light brown, and finally a light brownish red lixivium profile (**Gr--W.NN.ae.3**). The most important of these massives are those of the hinterland of Moeara Boengo and of the Angai mountains in Djambi, of the Barisan behind the Goenoeng Dempo and of the Pematang Sawah mountain in Benkoelen, of the Boekit Garba in Upper Palembang and of the Oeloewaisemang mountains, as well as the Soelan massive in the Lampongs. As a rule these profiles are not very deep.[220] The penetration of the weathering proceeds slowly and many times the erosion is severe. Consequently not only are the finer weathering minerals washed out, but also much sand, for the quartz sand which has been freed as angular xenomorphic grains, is eroded off before a thick weathering soil is built up. Sometimes stones are found with a distinct weathering crust, in which the original rock can still be clearly recognized, although all the minerals except the quartz, have been taken "away." It is upon the iron content of the parent rock[221] that the nature of the resulting soil depends. With much iron the soil is very pervious, with little iron significantly less so. Naturally tropical high forest grows over the entire region. In the lowlands but little humus accumulates under this, while in the mountains much humus accumulates on and in the surface soil. Thus the roots of the vegetation can obtain their food at two levels, especially above in the humous surface soil, less beneath in the still little-weathered, juvenile layer of recently disintegrated granite, which the Germans call "Zersatz." Between the surface soil and the fresh zersatz there lies a thinner or somewhat thicker layer of leached lixivium of brighter color. --This is what develops on convex terrain. If the surface is flatter or concave, then in or just under this second horizon rather generally is found a layer of red lateritic concretions.

(2) On the crystalline schists, which are usually found only in the Lampongs, there also forms a pale, brownish red lixivium but this is somewhat more clayey. At the same time in many cases this lixivium also possesses more quartz sand than that on the granite; especially when it has developed from the mica quartzites and some of the gneisses. Elsewhere

220. See: J. Szemian, Agrogeol. beschr. in Geol. Kaart V. Sumatra 3 (Bengkoenat), p. 41. Soil profile not even 1 meter deep.

221. We may compare the analyses of pp. 517-519. In addition to these analyses and personal observations of an earlier time (1909-1917) and a later period (1931), I am also thankful for the use made of data received by letter from J. M. K. Szemian, in assisting the development of the hypotheses of this chapter.

Regarding the Way Lima Region in particular, see: J. Th. White, Bijdr. kennis v/d agrogeol. v/d Way Limestreek., Meded. Alg. Proefstation v/d Landbouw 19 (1925).

there is much similarity in characteristics between the ways in which weathering takes place and soil types on the granite, etc. previously mentioned, and on these crystalline schists. But where these schists become more basic in composition and consequently are developed as amphibole schists or amphibolites, chlorite schists or actinolite schists, there the soil types might also show more similarity with those originating on dacites and andesites, although without doubt there would also be essential differences. However, to state these relationships accurately is not yet possible. It will have to be done sometime in the future.

The soils under groups (1) and (2) all react more or less acid. The average pH is around 5. Even into the "Zersatz" horizon, in which the rock structure is still preserved, this is the case. It is indeed an indication as to how under these tropical conditions chemical weathering runs far ahead of the mechanical comminution. "The exchange and the hydrolytic acidity increase strongly with depth," says Szemian on the basis of his analytical figures. Nor does the possible explanation that the deeper layers should be more leached than the upper appear very probable. The reason must be sought in something else and then one wonders as to whether or not in the deeper layers there still occur colloids saturated with bases, which have either been leached out of the higher layers, and thus carried away as sols, or which through the aging have gone over into another form in which they can hold only smaller amounts of bases absorptively. It may be expressed in another way, using the recognized symbols S and T. It is less probable that apart from the uppermost, humous layer, the S decreases as the depth increases, than that from below upwards the T decreases. However that may be, an experimental study regarding this is very much to be desired, less for a knowledge of the local conditions than to enlarge our general understanding of the phenomena.

Because of the topographic position and nature of the surface, peat is not to be expected on (1) nor on (2). The low and concave portions are covered over by other parent material (see later) and the higher parts are not high nor are they cool enough. Moreover they do not lie flat enough to make possible conditions favoring peat formation. On the higher portions, at about 800 to 1,000 m. where untouched tropical high forest has been allowed to stand, there is naturally to be found an excellent humous surface soil. But as soon as the forest is cut by the natives, and that humous surface soil is washed off, for the time being the forest vegetation disappears and the humus content and the fertility of the soil seriously decrease.

(3) We can say the same of the soil types on quartz sandstones, loam, loam-slates and clay slates from the Pretertiary and Old Tertiary, which fortunately but seldom occur in this form on the surface in South Sumatra. On the sandstones, just as elsewhere on Sumatra, a pale brown to grayish white, sandy lixivium with a very modest surface soil occurs which, because of some little humus, is darker in color. This is especially true when miserable, open forest (which is all it can support) stands on this soil. The clayslates carry a better forest, especially whenever the original clay had been a marine or brackish water clay. Yet deforestation is also fatal for this soil on the clayslates, since on the frequently brightly flecked red-yellow-white-brown-orange heavy subsoil under forest there lies but a thin layer of grayish brown humous surface soil. Because it is looser and takes up relatively much rain water this soil also erodes off swimmingly. There is left behind a particolored subsoil on which, however, there is possible an earlier reestablishment of the vegetation than on the sandstones.

* * * * *

As their time of formation had been more recent geologically the other Tertiary rocks in Southern Sumatra all contain an increasing proportion of tuff, so that in their youngest form, the so-called Upper Palembang strata, they are practically pure volcanic tuffs. Hence it is obviously quite in order to speak particularly of the soil types on exclusively volcanic material. For the small spots of younger Tertiary, which do not consist predominantly of this material, the reader can easily deduce the

soil characteristics so they do not deserve separate discussion.

(4) Everywhere on the "old andesites" a yellowish brown or reddish brown lixivium has developed, which for the greater part must be called senile. Where these old andesites had been more or less hydrothermally silicified before they began to weather down to soil, we find as a residue in the residual soil numerous broken fragments from the chalcedony and quartz veins and little veins from the broken blocks. Originally the fragments of the veins which had been in the rock remain in their original places, later they get shifted about. If the surface layers exhibit a certain periodical movement (be it the result of differences in temperature, alternating drying out and becoming moist again, or creep), while the deeper portions of the soil do not move in response to those influences, then stones and gravel in the surface layers do not remain in their relative position, but move upwards or downwards. In this way great blocks frequently come just to the upper surface, also smaller stones are worked toward the surface of the soil, especially by strongly shrinking and swelling clay surface soil or higher horizons. But from the soil horizons lying deeper, gravel and small stones sink downwards to approximately the level where the soil is at rest, and there form a gravelly and stony horizon. When studying a profile by boring or digging, such an accumulation gives the impression that it is a weathered, originally sedimentary deposit. From the above explanation this is seen to be incorrect, for we have actually to do with a layer of gravel concentration formed in and segregated from a residual soil.

Concerning the soil on the crystalline schists of the Lampongs, Szemian[222] observed "....under the brown (surface-) layer there is a reddish brown lixivium zone which sometimes contains red lateritic concretions and angular quartz fragments and which with increasing depth grades into a red-, yellow-and gray-flecked clay containing quartz sand. A large number of quartz stones collect together between the two last-mentioned layers and form a coherent quartz gravel layer hindering plant growth. The transition between the flecked layer and the parent rock, however, is gradual...." Here we have mention of a gravel horizon as described above. Also with respect to the soil on the silicified "old andesites" Szemian records[223] that "In the subsoil sometimes quartz stones occur, which as a result of (creep), have most times accumulated into a layer." Further on, when the "talang" flats of Palembang and Djambi are spoken of, the reader will find still more about this sort of gravel horizons (p. 544).

(5) The outcrops of solid rocks of acid, dacitic or liparitic composition play too small a role in soil formation to justify their discussion separately. On the other hand on the tuffs from this sort of material in the long time since their formation there have developed yellowish brown to reddish brown, quartz-containing lixivia. The quartz crystalls remain unweathered and the feldspars, mostly poor in calcium, also weather with difficulty, but the glass has for the greater part broken down and gone over into clay which is paler and stiffer the smaller the proportion of dark minerals present in the original tuff. As to this clay, the following facts have been found out about the clay minerals.

Under the broad conception "clay" there are included various clay minerals about which divers things have already been stated on pages 77-78. In a paper on "The formation of Minerals in the system Al_2O_3--SiO_2--H_2O" Noll[224] treats of the formation of clay minerals in nature, from which there comes to light the here important distinction that on good lands it is not only likely but even probable that from minerals such as the feldspars kaolin forms upon weathering under the influence not only of pure water, but also of acid water, thus carbonic acid-containing, or sulfuric acid-containing, or humic acid-containing water. On the contrary under the influence of alkali or

222. J. Szemian, In an explanation of concept on sheet 1 of the (not yet published) Agrogeol. kaart van Sumatra (1929).

223. J. Szemian, Explanation of sheet 3 of the Geol. Kaart v. Sumatra (1933), p. 38.

224. W. Noll, Neues Jahrb. f. Min. Geol. Pal. Beil. Bd., 70., Abt. A. I (1935), pp. 65-115.

OH ions, montmorillonite is much more likely to be formed. Accompanying the kaolin, in a certain sense, is also halloysite, while beidellite belongs with montmorillonite. The first two thus form when the pH is less than 7, the two last with a pH above 7. Apart from crystallographic and optical differences in which the reader will be less interested, there is, however, a difference of another nature, one of real significance for us: kaolin and halloysite have only a small capacity for absorbing such ions as Ca, Mg, K, Na, and NH_4, namely about 3 to 15 m. eq. per 100 g. dry matter, while montmorillonite can absorb 60 to 80 m. eq., and beidellite similar quantities.

Accepting the theory that the contrast mentioned is a matter of formation, only to be established through further experience, attention may then at once be called to the following contrast: In a very humid climate a rising of the pH to above 7 is less to be expected than in a continuously or intermittently arid climate wherein the bases liberated by hydrolysis are not leached out to such an extent and thus remain present and raise the pH to above 7. Further, with slow weathering of acid, K-rich and Ca-poor rocks, especially compact granites and quartz diorites, but also liparitic tuffs, the pH will sooner fall below 7, thus the water will sooner be acid. But on basic, Ca- and Na-rich andesites, and especially on rapidly weathering basic tuffs, in the beginning the pH will certainly rise above 7. The consequence is obvious. On the Sumatran granites in that very humid climate, kaolin will be the predominant product with perhaps also halloysite, with a small absorptive capacity. While on the acid tuffs under the very same climate montmorillonite is the principal weathering product. These tuffs, however, are primary marine tuffs. Then since the pH of sea water is 7.8-8.4 and between the tuffs there is calcium of organic origin which also raises the pH, the amount of montmorillonite formed certainly is very much greater than that of kaolin, so consequently the absorptive capacity for bases of soils from such rocks is distinctly higher. Because of the slow weathering of solid andesite and basalt, such as the "old andesites," the pH will seldom rise above 7, and thus the soil weathered from them will obviously possess more kaolin than montmorillonite. As a consequence the possibilities of absorption will be but moderate. On the basic tuffs, on the other hand, montmorillonite is to be expected. However, these distinctions will be all the sharper in a climate such as that of East Java and the Smaller Soenda Islands. At first more montmorillonite forms, as well as less kaolin, and besides, since the ground there is less leached, less washed out, the montmorillonite is still more saturated with bases. Perhaps on the basis of these newer conceptions of weathering processes, it is now also possible to find an explanation for the formation of the black lands of the alternating climate where the wet and dry seasons are more pronounced, as well as of the semi-arid savanna regions. The possibility that the montmorillonite with its great power of absorption which absorbs not only the usual basic ions, but also bivalent and trivalent iron, perhaps opens a way to the explanation of the structure. But without closer study anything more about this cannot now be said.

Coming back to the soil types on the pale tuffs in the mountains of Southern Sumatra where forest still covers the terrain it is evident that the higher one goes, the more humus is still present on and in the surface soil. Yet this humus layer is but moderately thick and if vigorous measures are not taken promptly against erosion, it rapidly disappears when the forest is cleared off. Besides in the higher, cooler regions the weathering of the tuff has still not progressed very far so that the soil there is extraordinarily pervious. For example on the tuff plateaus northeast and east of the Piek van Korintji, northeast from the Boekit Nilo and Boekit Mesoerai, on the eastern part of the Pasemah plateau, and northeast and southeast of lake Ranau, this sandy subsoil is many times not only meters, but tens of meters deep. This subsoil seems to have a sucking down effect, so to say, upon the moisture of the surface soil. As a consequence the soil is not able to retain enough moisture for the needs of the vegetation. Where, however, the weathering has already reached the 2nd or 3rd stage, the clay content and the water capacity of the soil have increased, which also makes the soil less pervious. Simultaneously, the supply of

bases has already to such an extent been replaced by hydrogen that both soil and water have an acid reaction, so that further weathering produces kaolin and halloysite, with a low absorptive capacity.

(6) The younger, basic rocks, andesites and basalt, as the reader knows, weather to lixivia richer in iron and therefore darker brown and red colored. These soils remain more pervious, even though they are already quite senile, and as a result of their originally quite high content of bases such as Mg, Ca, and Na with K also adequate, are more suitable soil types for cultivation. The slopes and environs of the still active volcanoes: Piek van Korintji, Kaba, and Dempo demonstrate this very well, as well as the considerable number of other volcanoes differentiated by the Geological Survey of Sumatra as "young volcanic" as contrasted with the "old andesites." There are certainly around twenty of these volcanoes shown on the sheets of the Geological Survey which have already been published.

When fresh these tuffs do not possess so much pumice stone as the acid tuffs, nor do they lie in such thick layers; thus they also do not so seriously draw down the water from the surface soil. Originally, because of much calcium and sodium, they have a basic reaction, thus they have provided the apparent requirements (see above) for the formation of montmorillonite in place of kaolin; and hence for the development of a large absorptive capacity in the soil. Thereafter, in proportion as these bases are again leached out by continued additions of rainwater, they develop a distinct degree of acidity. This should explain the reason for the conclusion at which Szemian arrived[225] regarding this soil type, namely as it becomes senile it becomes even more acid, especially in the subsoil, than the soil types richer in quartz formed from acid tuffs. Indeed, the maximum figures for the exchange acidity as well as for the hydrolytic acidity are twice as high as the analogous values for the acid pumice stone tuffs. But comparing these soil types in this way is not fair, since the soils developed from the acid tuffs possess much more sand. If we consider these degrees of acidity to be an almost exclusive function of the colloidal constituents, then from the tables of Szemian for the different layers of the recorded soil types, we can estimate approximately from the fractions less than 2 mu. the degree of acidity by multiplying the given figures for the hydrolytic acidity and the exchange acidity with the ratio: $\frac{100\%}{\%\ \text{fraction less than 2 mu.}}$ and then it appears that for all depths in the profiles the acidities of the colloidal fractions on the acid tuffs are several times greater than those on the basic rocks.

In none of the previously treated soil types do there appear so clearly the differences between the different phases of weathering as in these soils originating from basic eruptives. It is quite obvious, for into this group fall the youngest formations of "parent rocks" which have come from the still active volcanoes: the Piek van Indrapoera, the Kaba and the Dempo; as well as Krakatau which was especially active just over half a century ago.

The last mighty explosion of Krakatau occurred at the end of August, 1883; and according to Verbeek[226] the efflatas, pumice stone and ash, thrown out at that time accumulated to the following depths at these various places:

on Krakatau itself	to	60 m. and more
on P. Sebesi Island		100-150 cm.
on P. Seboekoe Island	about	60 "
at Ketimbang on the coast, west southwest from the R. Basa	"	30 "
at Telokbetong	"	20 "
on the Vlakken Hoek	"	20 "
at Kroëe	"	6 "
at Moeara Doewa	"	1.5-2. "
at Tebingtinggi	"	1.5 "
at Benkoelen and environs ..	"	1 "
in southwestern and eastern Palembang	"	0.5 "
at Djambi	"	0.1-0.2 "

Volcanic ash fell on the mountains of the Lampongs to a depth of from 5 to 20 cm. With a volume weight of around 2, this amounted to between 1,000 and 4,000 tons

225. J. Szemian, in the above-mentioned "Tekst, enz."
226. R. D. M. Verbeek, "Krakatau" (Batavia, 1885), pp. 128-130.

Table 112

MECHANICAL ANALYSES OF KRAKATAU ASH: PURE AND MIXED WITH VARIOUS SOILS

Layer Nos.	Profile Description	2-1 mm.	1-0.5 mm.	0.5-0.2 mm.	0.2-0.1 mm.	0.1-0.05 mm.	50-20 mu	20-5 mu	5-2 mu	2-0.5 mu	less than 0.5 mu
426-II	Layer "pure ash"	3.0	7.2	6.5	8.9	15.1	30.5	18.9	4.4	2.9	2.2
488-II	" " "	3.2	5.2	5.6	8.1	18.3	30.1	18.0	5.7	2.9	2.2
	average about	3	6	6	9	17	30	18	5	3	2
267-I	on a subsoil from andesite	3	4	5	11	11	23	22	9	6	6
267-II		2	2	2	7	5	10	15	11	14	32
267-III		1	1	1	3	3	6	9	10	15	51
267-IV		3	1	1	3	3	7	11	10	13	47
442-I	on a subsoil from Soekadana basalt	1	2	3	7	10	19	26	13	9	9
442-II		0	0	0	1	2	6	9	10	16	56
442-III		0	0	1	1	2	8	8	7	15	58
96-I	on a subsoil from granite	2	5	8	13	17	23	20	5	3	2
96-II		6	6	11	18	19	5	5	5	10	15
320-I	on a subsoil from granite	2	5	7	15	14	19	19	9	5	4
320-II		2	4	5	12	10	7	12	13	16	19
320-III		4	4	4	9	8	6	8	9	21	27
320-IV		4	4	3	7	7	5	9	9	22	30
320-V		5	3	3	7	6	5	9	9	24	29
116-I	on a subsoil from crystalline schists	2	5	8	12	21	23	18	6	3	2
116-II		3	4	6	9	18	14	13	9	10	14
116-III		4	4	5	7	15	12	12	9	12	21
116-IV		2	2	3	5	11	11	13	10	17	27
116-V		2	4	4	7	13	13	12	8	13	24
116-VII		1	4	7	9	16	16	13	6	10	19
116-VIII		1	5	6	8	14	16	14	8	11	18
237-I	on a subsoil from dacitic tuff	2	3	4	11	12	29	24	7	4	4
237-II		1	2	2	6	8	20	20	9	12	20
488-I	material washed on, somewhat marshy, above dacitic tuff	1	3	4	11	15	32	22	6	3	4
488-II		3	5	6	8	18	30	18	6	3	2
488-III		1	1	2	7	12	42	21	6	4	5
488-IV		0	0	0	1	4	12	10	5	10	58
449-I	on alluvial, gray subaqueous clay	2	5	6	8	9	33	25	6	3	3
449-II		0	0	0	1	1	10	17	11	25	34
449-III		0	0	0	2	2	9	13	10	26	37
404-I	on the black clay of the Rawah Ratai	2	5	4	8	6	22	20	11	9	12
404-II		0	0	1	1	1	6	9	10	20	52
404-III		0	1	1	1	1	6	9	9	20	52

per hectare. If with this we take into consideration the analyses of the ash already recorded in Tables 11-17 then it is evident that by this one eruption an enormous supply of weatherable mineral reserve material was spread out over the soil surface. And since in general the soil of these regions was already relatively senile, we can certainly speak of a considerable "rejuvenation" of the Lampongs soil as a result of this one eruption.

Of course, from the very moment that the ash fell, in part even as wet mud, it commenced to wash off. Convex parts of the landscape, as ridges and peaks, were washed off more or less clean by the rain, the more so as these parts lay higher and had steeper slopes; hollows and swamps received a double quantity. From many places the ash was washed off as a mixture with a portion of the older underlying soil. This erosion may have occurred much later for now already more than half a century has elapsed since the eruption when the soil was more or less deeply buried.

On the rejuvenated, fertile soil all sorts of vegetation developed. The weathering started in vigorously and on the surface of the soil a humous surface horizon was formed. Even so the presence of the ash from Krakatau still can be demonstrated in the soil in various other ways, such as by the curve of the mechanical analyses, recorded in the tables by Szemian[227] following the "Tekst." Nos. 51, 410-II, 426-II, and 488-II are stated to be "pure ash," but the mechanical analyses of only the last two numbers are given here (see Table 112, page 529). From these there appears the characteristic peak in the fraction 50-20 mu., flanked by considerable percentages in the two fractions lying on either side. If one keeps in mind these fractions between 100 and 5 mu., and realizes that a little variation is to be expected, be it more toward the coarse, 250 to 100 mu. fraction, or toward the finer, 5-2 mu., then the ash may be recognized everywhere in the profiles below (see Table 112, page 529).

<u>Evaluation and Utilization of the Soils</u>

This mountainous region of South Sumatra, from the Piek van Korintji to the Soenda Strait, is indeed an extensive region which should be treated as a whole from an economic point of view and at the same time with a sufficient amount of detail.

And yet--I again repeat--there is no basis for a definite subdivision. For if we roughly take the entire volcanic mountainous region and the region that from a historical-geological point of view is not such, we need think only of the predominantly tuffaceous character of the sedimentary rocks in both regions to realize that the rocks appear to be practically the same petrographically and pedologically. From this last-mentioned standpoint the crystalline schists are also to be mentioned in the same breath with the older deep igneous rocks, the granites, diorites, etc.

Consequently, except for the ash covering in the south resulting from the youngest Krakatau explosion, with respect to the evaluation and the use of the soils, South Sumatra offers really no new points of departure. The effect of this explosion, however, did not reach as far as Korintji, nor was there much effect in Upper Benkoelen. Hence in these regions the parent rock determines the character of the soil in the same manner as was indicated in the preceding section dealing with the nature and the value of the soil. And this value is closely correlated with the possibility of cultivation, food production, and density of the population.

According to the map upon which the <u>density of the population</u>[228] is given with no more detail than by subdivisions, Moko-Moko and Bangko, with not even 5 inhabitants per km.^{2}, appear to be the thinnest inhabited of the whole mountainous land of Sumatra. The parent rocks of the soil of those districts are Pretertiary formations, in part covered over by acid

227. J. Szemian, <u>l. c.</u>

228. See table 9 of, and the map following, in: Volkstelling (1930), Dl. IV, Inh. bevolk. Sum. (Batavia, 1935).

tuffs, which because of their great porosity do not retain sufficient water for cultivated crops. The Lebong subdivision, including Moeara Aman with more old andesites and a few small plains, has somewhat more inhabitants (14 per km.^{2}). Then with the younger volcanoes Beokit Kelam and Boekit Kaba there follows Redjang with Kepahiang (23 inhabitants per km.^{2}); next to which lies Tebingtinggi (21), without volcanoes but with rivers, such as the Moesi. The Pasemah lands including Pagaralam (37), with the active volcano Goenoeng Dempo, are still a class higher; but Lematanghoeloe (24) and Lematang-hilir (26) are again lower. Following these we come into the more acid tuff lying over old andesites, and the figures for the density of the population sink further: Oganhoeloe with Batoeradja (19) Moearadoewa (18), Komeringhoeloe (13), Kotaboemi (12), Kroë (9). But in the south of the Lampongs the population again runs up somewhat, for Kota Agoeng has (15) and Telokbetong (38). The Krakatau ash should apparently be given the credit for these higher figures.

Of its very nature a statistical consideration, such as is given above, is but very approximate and rough. If, however, one could but subdivide the territory into smaller districts (margas), then the figures would tell us a good deal more. Yet the 1:100,000 topographic maps also indicate where the soil is of a sort to produce crops to support many people. From the most northeast-lying sheets, in so far as they have been issued, including Nos. 96 to 98, all together cover around 4,000 km.^{2}, and a high estimate for all the inhabitants in the 2 to 3 small villages shown in all this area is around a hundred people. Much very old andesite, much rhyolite (Mt. G. Seblat) and also acid tuffs and some Neogene deposits are the parent rocks of those lands, apparently too poor even for settlements which demand even only little. In the Lebong stretch the entire population is concentrated in and around the plains of Moeara Aman and Tapoes. Manifestly the material which has been washed off from the surrounding old andesites and other rocks and there accumulated is agriculturally of much higher value that what remains behind on the slopes.

Around Boekit Daoen mountain (sheet 70) conditions are somewhat better. This is confirmed by the small villages, many foot paths which presumably lead to kaiñgins, and even European estates, which this map shows. But the young volcanoes Boekit Kelam and Kaba are indeed quite good. Around and on their lower slopes they carry a complete garland of European coffee and tea estates. The map also shows many bamboo stands on the further eastern foot, to the left and the right from the road from Tebing Tinggi to Moeara Saling and further northwards. Bamboo is always an indicator of volcanic components in the soil which supply adequate quantities of soluble silica.

Besides the Kaba lies the Boekit Besar of the completely uninhabited Goemai mountains. Not much fertility is to be expected from "silicious clay slates" (see pages 514, 525) which constitute the parent rock. Yet higher up this mountain, especially toward the east and along the edges, it is not so infertile, thanks to inclusions of eruptive material and limestone, yet there are not any settlements at all.

If we now consider the Goenoeng Dempo, then we are at once struck by the Lintang valley lying north-northwestwards from the mountain and thickly inhabited, full of paddies. Behind the Dempo also lies the small, but thickly inhabited plain of Tandjong Sakti. These two localities have of course a very juvenile soil with a large proportion of basic volcanic ash components. Besides, this soil is sufficiently pervious and at the same time also holds an adequate amount of water to make the cultivation of all sorts of crops as well as paddy possible.

East from the Dempo, however, lies the largest part of the Pasemah plain, for a large part still unused. Trials of coffee and rubber cultivation were not successful there. Walking through the scanty grass,--cogon will not even grow there--again and again one stumbles over old paddy dikes, which indicate that in previous times paddy culture was carried on, or at least there were attempts to grow it. It seems to me probable that the growing of this crop was given up because (1)--the soil had become too senile, thus too poor[229] and because (2)--the ravines finally cut down too deeply

229. Perhaps we must here also think of the disappearance of the original forest humus and what has already been said about that on pages 475-477.

below the surface so that irrigation water no longer could be led out onto the paddies. Most of the villages and paddies are still found against the foot of the smaller, although also quite old, volcanoes Boekit Moetoeng and Boekit Rawis, in the southeast of the plain. Apparently in that locality there is available somewhat more water as well as water of a somewhat better quality. At present, however, the greatest part of the plain is quite valueless and useless, and waits for a "rejuvenation" by the Dempo.[230]

Next to the Pasemah lies the Semendo, a spacious relatively thickly populated valley, surrounded by a number of geologically still young, but pedologically quite old volcanoes. The Boekit Nanti (sheet 54), also an old andesitic volcano, deeply fluted, and thus with a very rough surface, is practically uninhabited. But in the Ogan valley, north therefrom, a number of tani profit from the material which has been eroded off from the slopes and deposited beneath on flatter terrain. In a similar manner also, the Upper Moesi valley is decently fertile and inhabited.

South from the Boekit Nanti and southeast from the Semendo lies the Kisam region, also for the most part surrounded by old, andesitic volcanoes. This region is notable because of a quite thick population living in quite scattered settlements. This is because here are no commercial centers, the Kisam is too remote for that, but apparently the inhabitants make a good living by simple subsistance agriculture alone.

Around lake Ranau the density of the population varies distinctly. Around the G. Seminoeng are settlements where but one paddy can be laid out. So also in the valley between the three high mountains G. Raja, Pesagi, and Koekoesan, but especially in the Liwa stretch between Negeri Batin and Kenali. There much Ranau efflata accumulated and formed a moderately undulating and for this part of Sumatra quite thickly populated plain.

The Ranau eruption was liparitic (see Table 109 ff.). The region produces tobacco, not high yields, it is true, but quality tobacco. Allow me to digress for a moment: the plain of Pajakombo is likewise built up out of efflatas of acid to intermediate composition, later basic Merapi products were added to it. Pajakombo also produces special tobacco. Deli cultivates tobacco on dacitic and liparitic soils, nothing like as basic as those of the Principalities of Java and Djember, which produce an entirely different type of leaf. Not alone the climate, but apparently also the nature of the parent rock, and the composition of the efflatas play an important role in the production of tobacco of a definite quality. This can be proved, but up to the present time it cannot be explained.

During the eruption referred to the previously-mentioned mountains of "old andesites" were later again covered over by the Ranau ash and then washed off again. Apparently they do not offer much opportunity to the native population to make a living: between lake Ranau and the coast lies a totally uninhabited mountainous region of a similar nature. Near Kroëe on the coast we see a small strip with many paddies and many people, behind that a sudden change to an uninhabited region. Also the numerous volcanoes around the Liwa plateau are practically speaking uninhabited, but what has been eroded out of them by the rivers, as the W. Oempoeh and the W. Besai, has built up the fertile Rebang strip.

Along the Semangka river there is also only a scant population to be found, the one exception is a few villages on the edge of the Soeöeng depression. If there were a first rate highway from Kota Agoeng on the coast, via Sanggi and Negeri to Liwa it would offer important new perspectives through opening up of plains and mountains which today are still completely cut off from the outside world. It is true that the productivity of the soil there will not be as high as that on the Kaba or the Merapi. The soils are already too senile for that, but even so we can yet expect a considerable fertility. With respect to the plains,--but these will first have to be drained--we can anticipate adequate irrigation water for reasonable demands.

230. Cf. E. C. J. Mohr, Tropical soil forming processes and the development of tropical soils, with special reference to Java and Sumatra (translated by Robert L. Pendleton), National Geological Survey of China, (Peiping, 1933), pp. 155-160.

East from the Semangka river lies an extensive, but very rough mountainous region of old andesitic volcanoes with here and there some liparitic ash coverings. This region is, for the greater part, uninhabited. Even the Gedongsoerian depression is also almost uninhabited, no doubt because of the lack of roads into this region. But the senile soil is certainly not so attractive that the population itself has overcome that transportation difficulty. I cannot help imagining that just as we expected for the Semangka valley, a good road from the Rebang in via Moetaralam, or in from the south would certainly here also have favorable consequences. It is true that as to quality of the soil, the Tandikat Tebak and the Boekit Rindingan have possibly received less material from the Goenoeng Tanggamoes. But all three are certainly better than the Oeloewaisemang Mts., lying east from the two first mentioned mountains and consisting of granite and schists. They are entirely uninhabited, and are destined to remain that way for some little time, even in the lower and flatter portions.

Finally in this connection Soekadana is shown on sheet 14 of the topographic map. On those maps we see how a complex of settlements lies between Soekadana and Boemidjawa precisely on an outcrop of basalt, while on the surrounding acid tuffs no population at all has established itself. Then we note population again on the edge of the basalt cake of Soekadana itself. In such ways, along empirical lines the native population demonstrates the close connection between parent rock and soil fertility.

Near to the terrain referred to, that is to say, west and southwest from it, lies an extensive region without a single earlier settlement already in existence on allochthonous acid tuff soils; on this land at Gedongdalem (Soekadana) it is proposed to develop the Javanese colonization scheme.[231] The first test plantings and test harvests have greatly exceeded the expectations of the agricultural scientists[232] and a conclusion has been arrived at in which I fully concur, namely that very probably the presence of a quantity of fresh Krakatau ash in the soil of this region has had an especially favorable influence. It is, meanwhile, a very important question as to whether these large yields are a phenomenon of only a few years, or if indeed they will continue to be obtained. Based on the fact that down to the present time the inhabitants have never continuously cultivated the white tuff plains referred to, a permanent high fertility is hardly to be expected.

* * * * *

When in general for the mountains of Southern Sumatra we endeavor to find data in the literature regarding the yields of paddy, be it of kaiñgins (upland unirrigated rice fields) or of paddies (lowland flooded rice fields), then the results are still more scarce than for a number of other regions.

In a few test cuttings of lowland rice in the year 1919[233] those in Korintji averaged 61 quintals per hectare padi (rough rice) which amounts to 36 quintals per hectare polished rice. "Indeed a high production in a year called average." Further details are lacking, though there is the unmistakable influence of the nearness to the young volcano Piek van Korintji on the fertility of the plain of Soengei Penoeh.

It is only strange that going out in other directions from this mountain there are so few native settlements. In the last two decades a number of European plantations have come into existence on the northern side. This can be considered an indication of great soil fertility. Whether this fertility will continue to last for a long time or not will depend partly upon the natural conditions, and partly upon the way in which the soil is cared for.

In 1931 along the road between Moeara Tebo and Soengeidareh I was struck by the fact that in the environs of Kota Baroe the excellent dark brown, loose soil was so significantly better than that on

231. F. J. Junius, Algem. Mem. Res. Lamp. Distr. (Mei, 1933), pp. 139-141.
232. Of the Institute of Soil Science in Buitenzorg and of the Agricultural Extension Service.
233. Versl. Landb. Voorl. dienst (1919), p. 332.

either side of it. More and better cultivated crops, even more productive paddies and vigorous fruit trees emphasized this impression. Yet this boundary region between Djambi and Sumatra's West Coast, to the southwest of Kota Baroe, is still but thinly inhabited. Perhaps in the direction of the volcano there could still be found a good location for many colonists. In his contrasting of the eastern and western portions of the subdivision Moeara Boengo, A. L. Samson,[234] also indicated something in this direction: the most lowland rice culture is found in the west (thus where the influence of the volcano must still be noticeable), also there the best tobacco is raised. In the east (along the rivers flowing out from sandstones, clay stones, etc.) the paddies are much less successful. In Bangko,[235] no paddies are found along the Merangin and its tributaries, nor along the other rivers either. Now this Batang Merangin is the one river which has its source in a lake (that of Korintji) and thus begins free from silt thereafter to flow down through the old rocks, while its tributaries also originate in similar materials and in acid tuffs. Never anything of a young volcanic nature, other than the acid tuffs, which apparently do not supply sufficient fertility to the water and silt. In 1931 Controller Rapp[236] wrote about this: "Along the Merangin the villagers produce crops only by kaiñgining. The water seems to be less suited for irrigation. The paddies now (1931) laid out there and transplanted to paddy have never yielded a harvest." In 1909 controller Meyer[237] recorded that in the Senggrahan district (through which flows the Soengei Nilo, a tributary of the Merangin and coming from the high Boekit Masoerai) a lack of food prevails there year in and year out. And in 1916 controller Boissevain[238] stated that in the three most northerly districts of Bangko, as well as in Bangko and Limboer on the Merangin and Rantaupandjang on the Tabir, a scarcity of rice always prevails and also in Senggrahan, even where there were paddies, while the first three districts mentioned had only kaiñgin agriculture.

In short--the sporadic and sometimes vague data as yet available show that if for a region such as Djambi we had an equally thorough knowledge of the soil, with as good a soil map as we now have of Djocja for example, we would have much light on what now without such data seem to indicate sometimes such apparently arbitrary and strange choices by the inhabitants as to the lands selected for cropping and the methods of crop production employed.

The more east-northeast mountains of Djambi, especially, have a red to brown lixivium soil, which becomes the poorer, the farther one descends, and more unfavorable in its water holding relationships as one goes higher. Happily in the southwest we find something else in the fertile valley of Soengei Tenang and Serampas, lying between the Boekit Masoerai, the Boekit Oeloe Nilo and the Goenoeng Soembing and on the other side, southwest, of the Goenoeng Pandan and the granite ridge to which the Boekit Boengkoet belongs. In this valley, at more than 1,000 m. elevation, we find a very humous, black surface soil on a brown subsoil of volcanic origin, possibly, however, mixed with some more binding components originating from the granite. Here tobacco, coffee, cinnamon, potatoes, and in general all sorts of vegetables, grow excellently and perhaps would be grown still more extensively if there were but transport and sale for them; as yet production is all on a relatively small scale. Rapp[239] says that "the soils of this mountainous region are excelled only by those of Korintji." Cabo negro (aren) palms indeed do occur and are planted out, but cocos will not grow here. For European estates there is not enough of this fertile soil type, and too large a proportion of what there is, is already under cultivation by the inhabitants. The valley is but relatively small and the

234. A. L. Samson, Mem. v. Overg. o. afd. Moeara Boengo (1915), pp. 31-33.
235. J. Bouwes Bavinck, Alg. Mem. v. Over. (1920), pp. 3-4.
236. G. Chr. Rapp, Mem. v. Overg. (1931), p. 10.
237. A. F. Meyer, Mem. o. afd. Bangko (1909), p. 26.
238. J. H. G. Boissevain, Aanv. Mem. Bangko (1916), p. 3.
239. Rapp, l. c., p. 1.

slopes around it are steep, clothed with "heavy forest in which are very good sorts of timber."

From the different notes of giving over charge by the administrators of Djambi Residency some more brief remarks could well be selected which would give some indication as to the soil. However, we are not here writing a monograph about Djambi, but rather about the soils of all Sumatra.

* * * * *

According to the agriculturist Koens,[240] Benkoelen, may be divided into three soil zones:

a. The lowlands and the hilly land lying behind it, largely Neogene. Here in general are found poor soils (note the high rainfall in Tables 89, 90). Yet the soils are still more or less rich in humus. As usual this is related to the elevation. Only in exceptional cases are these soils irrigable, while the kaiñgins give no rich harvests. Along the sea the soil is looser, sandier, and grows good cocos. Higher up the inhabitants raise gambir, pepper, nutmegs; the yields of these crops, however, are none too good.

b. On the older mountainous lands agriculture can be called successful only on the old andesite. There the paddies yield well; also the coffee. The kaiñgins are better than those mentioned above under (a)--

c. In the young volcanic regions, on and around the Boekit Kelam and the Kaba, the agriculture has attained a much higher development. Here are rich kaiñgins as well as good paddies. In 1915 I saw very good coffee especially upon land just cleared of heavy tropical high forest.

So much for what Koens has recorded. His classification brings us no new points of view, only the confirmation of the expectation which we had already based upon the general broad lines.

To supplement these there follow a number of statements from Resident Zieck,[241] with some explanatory remarks of my own:

"The entire coastal strip along the road from Benkoelen out toward the northwest makes a poor impression. The population is very sparse. The plantings of nutmegs, cocos, and coffee are of little significance. Farther inland the inhabitants have their gardens and kaiñgins while on the lower bits of land paddies are laid out. Their extent is still small."

"At kilometer post 25, near Kerkap, a more important village, a road branches off into the interior toward the townships Perbo and Palik. Here there is a sudden change to better soil conditions, and as a result there are larger planted areas and more extensive paddies, while the natives themselves also make a definitely better impression." The reader will understand this if he looks on the map and notes that the rivers and hence the youngest soil material covering over the surface is coming from the already repeatedly-mentioned volcano Boekit Daoen.

"Beyond Ketahoen the road runs" (along the foot of less valuable mountainous land) "through an uninhabited stretch." --"Mokko-mokko is one of the poorest subdivisions of the district.--Beyond Aer Dikit and on to Loeboek Pinang the land appears to be better suited to plantation crops than that lying on the coast." However, this is to be expected since also this land has as its hinterland the Korintji volcano!

Southward from Benkoelen the road runs through the coastal strip of Seloema, which has "a poor appearance. The land there is not so good," and since one of the sources of the soil material is a strip of Eocene sandstone in the hinterland, it can probably never be expected to do much better and, especially since there are "endless swamps," it can hardly be very fertile. "In Manna large plantings of clove trees begin to appear; still farther toward the south are also pepper gardens." The Ajer Manna comes also from the G. Dempo and flows through the plain of Tandjoeng Sakti, which has become one solid field of paddies and very prosperous.

Going further along the coast through

240. Versl. Landb. Voorl. dienst (1915), p. 196.

241. W. J. R. Zieck, Aanv. Mem. v/d Res. Benkoelen (Febr. 1932).

Kaoer, toward Bintoehan, "one sees always more clove and pepper gardens." Out of the interior comes coffee." Here I cannot make out a definite connection with the soil type nor explain why "south from Kroë the coastal strip is definitely poorer than north from there. Northwards are choice paddies, southwards principally kaiñgins, while the inhabitants also gather forest products and have some coco and pepper gardens." Further on southwards, beyond Bengkoenat, on to the Vlakken Hoek not a soul is living. The land lying behind the mountain is likewise entirely uninhabited.

Behind the first Barisan range, however, the country is significantly better.

From Benkoelen out toward the east the road runs toward Kepahiang and Tjoeroep. "The strip through which the last-mentioned road goes is excellent and well inhabited." And it should be, as it also lies on the foot and up the slope of the Kaba. "The land is excellent and the plantings are seen to be extensive. Many Javanese, formerly contract coolies, have settled here." In this they show their good judgment of the natural fertility of this soil.

The plain of Moeara Aman is a filled-up valley, which appears as if it had once been a lake, but then certainly not entirely, for here and there on the surface, out to practically the middle, are scattered large lahar boulders. It is now "already mostly transformed into paddies." As to their yield, however, nothing was to be found other than the remark of the agricultural adviser that "From the large average paddy area annually an excess of rice is obtained, but not because of a high average yield."[242]

Going out and upwards from Kroë we approach the plateau of Liwa, a large undulating region of washed-together Ranau ash (cf. Figs. 30, 31, page 163). "The soil is very fertile and excellently suited to all sorts of mountain cultures." Coffee especially is grown here, but relatively small amounts of food crops, due in part to the elevation which is about 900 m. This plateau, as well as the very out of the way plain of Tenong (Gedonegsoerian), ought to have better connections with the outer world. If more good roads were built into that country it would be more thickly populated. In general the soil is a relatively senile brownish yellow lixivium on older and younger intermediate andesites; and because of the elevation the soil certainly still has an adequate humus content. In this high land it is not necessary to be dependent upon the cultivation of rice....; potatoes and greens grow just as well as maize, cassava, peanuts and sweet potatoes. Apparently even here also the soil has been somewhat rejuvenated by Krakatau ash. Rice can be grown quite well here, both lowland in paddies as well as upland in kaiñgins. The upland type is being extended more and more, since because of low prices the cultivation of coffee appears to be no longer profitable.

After seeing the favorable soil conditions in the Sumatran mountains with their generous areas of brown and yellow volcanic soils, it is comprehensible that where the circumstances are but only slightly favorable, irrigation works are laid out. To the north, on Sumatra's West Coast the density of the population necessitated that this be done there all the earlier. But here irrigation has more future than past. In so far as the mountainous land of Benkoelen is concerned, in the Kepahiang region irrigation is quite the farthest developed. There especially the works are small, serving not even 700 hectares each. It is not because of a lack of water that there is a need to irrigate in these regions of abundant rain. The land is irrigated really only because of the plant food substances which are brought on with the water. Obviously it is imperative to study the water before new irrigation works are laid out. Once this has been done it is very probable that several different rivers, even only after casual inspection, will have to be struck off from the list because of unsuitable water.

In that respect also, especially in the Lampongs, great differences are to be observed. For example, without exception the rivers flowing off from the Tanggamoes are suitable for irrigation. Toward the south the environs of Kota Agoeng are thus benefited, and similarly toward the east the Poegoeng region. But as to the quality of the water, the Way Sekampoeng is not very much. Because of their good

242. Zieck, l. c., p. 32.

tributaries the Way Sangharoes and Way Ilihan are still not so bad, but the upper course of Way Sekampoeng itself, with a number of affluents coming from the Oeloe-waisemang mountains to the north, is so poor that in that locality there is not a bit of paddy. The strip is completely uninhabited and apparently will remain that way for some time. If, however, a road is put through along the upper course of the Way Sangharoes, inhabitants will indeed be settling there.

Finally, a few words regarding the region around the mouth of the Semangka river, which is to be thought of as a filled-up arm of the sea. The surface soil, however, is universally river silt from this river, in the lowest part swampy and leached to a gray, subaqueous lixivium, surrounded by a narrower or broader gray strip of more amphibian nature, as may be seen on the small map of Szemain.[243] Outside of that lies brown (virile) and reddish brown (senile) andesitic tuff lixivium. A quarter century ago this delta was considered hopeless, and quite uninhabitable, a point of view which even at that time seemed to me as inconceivable as did the generally unfavorable opinion about the delta of the Tjitandoewi on Java, and other similar deltas with young volcanic hinterlands. At present on this Semangka delta there is established the Javanese "Wonosobo" colony which is paying its own way, even though there are indeed difficulties. But on the average the paddies yield 35 quintals per ha., which is not so bad. It thus appears that this plain will, within a reasonable time, be converted into one continuous paddy plain. The lowest parts, which still now suffer from the inconvenience of too much water, should be colmataged, i.e. first be diked, then flooded with silty river water so as to considerably raise the ground level with the river sediment.

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7. THE EASTERN LOWLANDS OF CENTRAL AND SOUTHERN SUMATRA

An appallingly large part of Sumatra, from the southeastern point on Soenda Straits to approximately Bilah, is included under this title. If we take the back boundary of this lowland to be roughly not more than 100 m. elevation, even then it includes half of all Sumatra. And yet since in various respects this lowland is indeed so uniform and is so much of one sort, we here treat it as a whole. As to the climate, that has already been described on pages 424-425, and in Table 95. As to the geological formation, the whole has been built up out of sediment during the present, and, speaking geologically, the most recent past. Igneous rocks, as such, play no role, although of course as sediments in the pulverized state they do.

Unquestionably these sediments are and were of different sorts. In the first place they are to be differentiated according to their origin. Therefore we must consider the rivers which carried out from the hinterland the material deposited as the sediments. In the second place the sediments are to be differentiated into marine sediments, later exposed above water, and terrigenous sediments. In the third place they are to be differentiated according to the period when they were deposited, thus according to the time which has elapsed since the deposit and the stage of weathering which has since been reached. Let us now consider the subdivisions we will use in this chapter. In the first place we shall divide this region we are considering into the (principal) drainage basins, according to the most important rivers. Beginning in the northwest and ending in the southeast these are:

1. the Baroemoen,
2. the Soengei Rokan,
3. the Siak river,
4. the Kampar,
5. the Kwantan,
6. the Djambi river,
7. the Moesi,
8. the Way Toelangbawan,
9. the Way Sepoetih,
10. the Way Sekampong.

If the river basins of these ten rivers are treated in the order here given, of the whole great region there will be left out only some small areas which drain directly into the sea through their own rivers or creeks. They are all as equally

243. J. **Szemian**, Korte agrogeol. beschr. bij. Toel. bl. 3 dor Geol. K. v. Sum. (1933), p. 39.

unimportant as the settlements of the natives along them. Where it is desirable, a few lines referring to them will be inserted in the proper places.

1. The Drainage Basin of the Baroemoean

We can boast about the Soengei Kwaloe and Soengei Bilah, lying somewhat more to the west, and which according to their nature properly belong in chapters 3 and 4 of this section on "Sumatra" because in the first instance they are flowing out of the region of the liparitic tuffs, that is, out of Habinsaran. The Baroemoen, however, arises from poorer materials. In so far as is known, its hinterland consists of little else than claystones, loamstones and sandstones, with here and there an inclusion of limestone or more or less calcium carbonate as a component of the abovementioned rocks. In this case whether these rocks are Permocarbonate, Paleogene, or Neogene[244] makes very little difference. The Baroemoen and its tributaries transport clay, fine and coarse silt, sand, gravel, and stones, of which probably only from the gravel and large stones can one determine from which group of rocks these sediment constituents have come. Calcium carbonate is to be found mostly in the coarsest pieces, because it is very quickly dissolved out of the finer fragments, and hence it is dissolved the more completely as the distance which the material has been carried out from the mountains increases. But quartz sand and clay do not dissolve in the water. Nevertheless, the clay can change notably in the course of such a river journey. Since the clay coming from easily disintegrated claystones or marls arrives in the river in great quantities, it is possible that apart from the fine calcium carbonate carried along with it, the clay itself, as an earlier absorptively saturated marine sediment, still tightly holds absorptively K, Ca, Mg, and Na. If it is but a short time until the clay again settles out of the water as new sediment in the low land, then it is perhaps yet not *entirely leached to "hydrogen clay" in which case the young deposit still possesses a certain fertility, which would have been lost if the river had been several times* longer than it is. But in comparison with those of the Rokan, for example, we must not suggest too great a fertility of the Baroemoen deposits since the back country is thinly populated, so that the erosion is still not so heavy as where more men live and disturb the natural equilibria. And so because as a result of the chemical weathering, even before the physical disintegration to silt, very much of the absorbed bases had been dissolved and carried away toward the sea.

There is something special about the Padang Lawas, a part of the upper drainage basin. The rainfall there is not remarkably low; no single month averages below 100 mm. and the annual average oscillates around 2 m. But some seasons seem to be unusually long and intensively dry. This is shown by the vegetation: predominantly grasses, cogon (Imperata spp.) and others. The reason for this drought is the descending, strong continuous west winds[245] coming over the relatively low part of the Barisan mountain chain, south from Padang Sidempoean, which for a considerable distance is not more than 400 to 700 m. high. These west winds come down as constant Föhn winds, dry and hot onto the plain of Padang Lawas at 100 to 200 m. elevation. This was why 50 years ago Neumann spoke[246] of an "almost treeless, infertile plain, of which Portibi occupies approximately the center." The plain of Oeloe Baroemoen, in which Siboehoean lies, seems somewhat better protected. The soil indeed seems to be better and more fertile. South from there lies the Goenoeng Malea, probably consisting of granite.[247] Whether an influence making for fertility goes out from this mountain, or whether the principal reason is an adequate supply of water, in any case the Oeloe Baroemoen plain is full of paddies and prosperous villages,[248] especially in the higher parts. Even so

244. See the map accompanying Zwierzycki, Blad. I der Geol. Overz. kaart N. O. I. archipel, Jb. Mijnw. (1919), Verhand. I.

245. Cf.: C. Braak, Klimaat van N. O.-Indië, II, pp. 70-72.

246. J. B. Neumann, Panc-en Bila-stroomgebied, T. K. Aardr. Gen., 2e Serie, II (1885), pp. 17 and 19.

247. At least Neumann,--l. c., p. 75--speaks of it as such; but on the map of Zwierzycki the G. Malea is not given, also no occurrences of granite are shown in that locality.

248. Neumann, l. c., p. 36.

there does not yet seem to be a surplus of rice. The Padang Lawas, an undulating hilly land of not 200 m. elevation, has the name of being one of the hottest parts of the Archipelago. It does not appear to be impossible that there are places where, on a very impervious substratum black earth has developed. It is true that Neumann has recorded nothing about it; and I have not found any later literature which says anything about the soil of the drainage basin of the Baroemoen and tributaries. The archeologist F. M. Schnitger, who worked a long time in the Padang Lawas, thought that he had seen black earth on certain spots, but far from everywhere.[249] It is generally known that on the extensive grass plains are pastured many cattle, which at certain seasons are sent on to Deli.

The lower drainage basin shows nothing in particular. Everywhere is the same picture. Stream banks which are natural levees formed by the sandy overwash of the strongly meandering river. At times loops are cut off by short cuts, forming low, sandy ridges in the land, away from the present river channel. Lower lands are between, which are always submerged, and are no different from the "danaus" of Borneo. The forests are uninhabited. Near the sea there are more people, since they go fishing there in order to keep alive; very few people live on the relatively high river banks. Close by the sea it is worth while to plant cocos on the river banks, for there they will bear nuts. If however, in the still low hinterland sea water with all its plant nutrients cannot back up the river that far and so cannot penetrate to the roots of the trees on the river banks, the trees although they grow quite well bear no nuts or at most only a very few. But to look for the limit where differences in level of the river surface because of the ebb and flow of the tide can be seen is, however, incorrect, since during flood tide the fresh water is backed up, without any salt water going nearly that far up the stream. It is also incorrect to look for the limit where the boundary between the fresh water and the salt water is on the surface, since in large and deeper rivers the heavier sea water penetrates as wedge-shaped tongues under the fresh water and in this way still can reach the river banks and make them fruitful, although on the surface only fresh water is visible flowing along these banks.

Now in the side creeks and shallow swamps back from the elevated stream banks this fresh water is of a peculiar quality: "ajer hitam," very clear, but colored brown to dark brown, "coffee colored" peaty and acid. Its pH is only 4, or even as low as 3, or sometimes even still lower. No wonder that extensive expanses of peat form in this strip of lowland.

If the reader is especially interested in the peat formations referred to, he should consult the special publications about them by E. Polak[250]; where are to be found very clear and comprehensive descriptions and opinions, which in many respects agree with my conceptions which appeared simulataneously (1933) in an earlier portion of this book (pages 111, 157). But not in all respects can I agree with Miss Polak.--

In contrast with "topogene" peats, the origin of which, according to Miss Polak, depends only upon particular topographic conditions irrespective of the climate, she calls the peats of the eastern coast of Sumatra "ombrogeen" and in the first place makes the climate responsible for their formation. However, it is extremely doubtful whether or not this distinction is valid. The author herself repeatedly recognized that when the topographic conditions are not fulfilled, as in a climate otherwise favorable for ombrogene peat formation (about 3 m. per year of rain, regularly distributed), still there is no peat formation. A typical case is that on the hilly land with red to yellow soils lying close behind the low coastal strip of eastern Sumatra, and only a few meters, or say a few tens of meters in elevation above the sea. Nor does the author record one single case of a topographic peat under a climate having a long,

249. Verbal communication to the writer.

250. E. Polak, Voork. veenafz. N. O. I., Vakbl. v. Biol. 14 (1933), 77. E. Polak, Veen in de tropen, De trop. Nat. XXII (1933), p. 117. E. Polak, Ueber Torf u. Moor in Nied. Indien., Verh. K. Ak. v. Wet. Amst. Afd. Nat. 2e Sectie. dl. XXX, 3 (1935), pp. 1-85.

dry season and at the same time at a low elevation, thus lying in a hot climate. It seems to me that the one principal factor governing the formation of the extensive peat fields in Sumatra, Borneo, etc., is the oligotrophic water conditions, poor in bases and acid in reaction. On this Miss Polak's work throws much light.[251]

And now a few additional points regarding peat: the older and the higher lying a peat soil is, that is the farther in toward the center of the "peat lens,"[252] the poorer the material must be in plant food substances. That trees still can exist on it is apparently because their roots extend down through into a substratum with much water which circulates freely, so that all of what little plant food is available, can be fully used. Rain and dust out of the air might bring down enough for a (scanty) replenishment of plant foods to supplement the broken down remains of the standing forest vegetation. After cutting down the forest and draining the peat, a soil formation results which, especially in outward appearance (see Fig. 28, page 158), very much resembles the high peat of the east of Netherlands and thus also should supply a very good "long turf," since through intensive leaching the ash content must be significantly lower.

The native population does not venture onto it for purposes of cultivation. Apparently on the basis of earlier experience they know that there is nothing to begin with. Here and there European planters tried to force plantings onto it. Only on the outer edges of the peat lenses where, after drainage and heavy settling, the peat layer has reached a thickness of not more than 1 m. Hevea seems to be able to reach down through the peat cover with its roots to the mineral soil below and in so doing can just barely remain "stationary." For palms (cocos and oil palms) to be able to get along at all the peat layer must be even thinner. But, even although the roots of the cultivated plants do reach the subsoil of clay (or the mineral substratum may be sandy) they do not get much. For it is a leached-out and bleached-out subsoil. Without intensive help from fertilization with an artificial fertilizer containing all the necessary elements for plant growth, it appears improbable that a plantation on Netherlands Indies peat can continue in full swing.

2-5. The Drainage Basins of the Soengei Rokan, Soengei Siak, Soengei Kampar and the Soengei Kwantan

It would indeed be superfluous to here consider these four drainage basins separately. The mutual similarity between them is too great to justify that. It is even difficult to point out particular differences between them and the Baroemoen. The only work in which anything regarding the soil of these regions has been recorded by anyone who, with an eye for such things, has travelled through the Bengalis division, is that by Bongers.[253] And what he has written will be found to be almost precisely the same as our description just above relating to the low land along the Baroemoen River.

The only marked difference is that the low land, that is to say, the land even the highest points of which do not exceed 10 meters elevation above the sea, is here twice as broad. These high "points" are flat, upward growing, peat lenses and river banks along the main rivers which still continue to carry out some sands from the hilly back bountry. On these stream banks these sandy ridges near Siak and Pakan Baroe, Bongers noted that the Hevea trees planted by the natives were in very bad condition. He also noted a few kaiñgins with upland rice, which was distressingly miserable.

No wonder that these extensive low flat lands belong to the thinnest populated regions of Sumatra, yes of the entire Archipelago. For the entire division of Siak the census of 1930 showed an average of

251. Miss Polak also includes with the topogene peats a couple of examples (Pangandaran and Ambarawa, both on Java) in which she supposes peat formation to be possible in a medium with an alkaline reaction. When considering "Java" I shall go into this point further.

252. Figure 29, page 159 shows a radial section through such a lens.

253. H. C. Bongers, Rpt. betr. de in de afd. Bengkalis voork. gronden, Alg. Lb. Wkbl. v. N. I., II (1920), p. 1277.

only 0.88 person per km.^{2}, altogether not even 30,000 persons. And of these obviously a sizeable percentage lived in the larger towns of Siak and Pakanbaroe and in villages on the river banks. The rest lived on a few low Neogene ridges, which lie between the Siak river and the Kampar, and between the Kampar and Kwantan. These ridges at most rise but 80 meters above sea level, while usually they are not higher than 30 m. But where the land does not rise above 10 m. and none of the large rivers flow through it, not a single person lives. There is simply nothing there to live on.[254]

As an exception to this we can mention the Chinese wood cutters (panglo-ens), in a strip of about 10 km. breadth along the coast. That they do not penetrate further into the interior appears to be because of the fact that the desirable woods are not to be found farther back.[255] In a certain sense the wood is a function of the soil:[256] (1) the salt water-mangrove zone gives a good charcoal wood and sometimes also tanbark; (2) from the second zone with more or less brackish water, lying behind the mangroves, on the places where the peat is still quite thin, weak but useful timber is obtained; and then follows (3) the region with the fresh, bright, "sweet water," which however reacts quite acid and in proportion to the depth appears to be brown to black colored. In this zone, on the top of the several meters thick peat, the timber is so poor that the Chinese wood cutters will not bother with it. Finally, in the center of the peat lens there stands almost no wood, only here and there a Pandanus. (4) Useful, hard wood is found only on the ridges and hills lying always above water, with yellow to reddish soil of poor quality so that the wood grows very slowly. But then this zone is above and out of "the low land."

For completeness it may here also be recorded that the large islands in the Straits of Malacca: Poelau Roepat, P. Bengkalis, P. Padang, P. Tebing Tinggi, P. Medang, and P. Menjalai all have the same soil types as does the low, main shore: a clayey coastal shore, here and there interrupted, sometimes by a sandbank, and sometimes by the inner formation which reaches the sea. Behind that is one great expanse of peat, running up toward the center to a couple of meters elevation. Inland the forest becomes worse and worse as one approaches the center of the peat lens. In from the coasts not a person lives. Only along the coast on some spots of clay, loam, or sandy soils which stand above the water level are there settlements of fishermen and wood cutters.

6. The Drainage Basin of the Djambi River

In comparison with the rivers discussed under 1-5 the Djambi river is of a different character, in so far as from here on to the south of Sumatra the upper drainage basins to an important degree have been and are still under the influence of volcanic eruptions which have produced enormous masses of efflatas. In the drainage basins of the rivers mentioned under 1-5, we were concerned practically entirely with the weathering products of sandstones, loamstones, and limestones. Products of volcanic origin played no role. But into the drainage basin of the Djambi river, however, there comes much, in fact very much volcanic ash. We have already noted this during the discussion regarding the mountains of Southern Sumatra (pages 514-537). The farther one goes south, the more the volcanic products predominate, so that the sediment which these southern rivers carry out is entirely different from that such as rivers 1-5 carry toward the sea.

For the greater part of its course

254. The new topographic maps on the scale of 1:100,000 are very striking in this respect for they do not show a single settlement! See also: J. Tideman, Land en Volk van Bengkalis, Meded. Encycl. Bur. Kolon. Inst. No. 9 and Ts. K. Aardr. Gen. (Nov., 1935).

255. A map of the pangloen regions may be found in: J. G. G. Jelles, Bosch expl. pangl. gebieden, Tectona XXII (1929), p. 484. See also: F. H. Endert, Proefbaanmetingen i/h pangl. geb., Tectona XXV (1932), p. 731. D. A. Boon, Bosschen voor expl. in Bengkalis, Tectona XXIX, p. 344.

256. Boon, l. c., p. 367--gives a very instructive, schematic sketch. However what he indicates as a clay ridge, had perhaps better be called a "bank," whether or not rich in clay.

Fig. 191. The road to Palembang running over the rolling talang plain of Djambi. Plantings of rubber by the natives.

Fig. 192. Djambi. Caving off in the outside of the meander of the Batang Tembesi because of which the road has had to be shifted over. The reddish brown lixivium evidently washes off more than the underlying pale clay layer. In the distance: village and talang vegetation.

the Djambi river flows through somewhat higher terrain than the rivers previously mentioned. Near Moeara Tembesi the Batang Hari and the Batang Tembesi unite. Before that near Moeara Tebo the Batang Hari receives the Batang Tebo, an important tributary. Below Sarolangoen the Batang Tembesi is joined by the Batang Merangin; while these are the principal affluents, there are of course still many of less significance.

The Batang Hari itself comes from far away--out of the Padang Uplands. From its uppermost drainage basin to approximately Soengei Dareh it does not receive much material for making particularly fertile sediments. But from there on the good influence comes out of the southwest, from the volcanic complex of the Piek van Korintji. Now it flows through, or more correctly under the tuff plateau of the Moeara Boengo division. We have already seen above (pages 533, 534) that there is certainly to be perceived a favorable influence upon the paddies, especially near the Soengei Djoedjoehan. Thereafter the river flows on out through the extensive Neogene regions of Central Djambi.

These young Tertiary lands already show the character of what throughout Southern Sumatra are called the "talang" lands; although here in Djambi it is customary to call them kasang lands, after a hard, tall sort of grass (Themedia arguens, Hack.) which grows here and which can easily be recognized by everyone.

The terrain is no low plain, nor is it mountainous, but a weakly undulating land between the two. Here somewhat more hilly, there almost entirely flat, but everywhere the surface is well drained, lying above the ground water (see Figs. 191, 192, page 542). A region analogous to the Netherlands' Veluwe, even as to the vegetation: here and there, especially in the valleys, is forest, not heavy tropical high forest, but rather a meagre secondary forest. Elsewhere extensive expanses of kasang and cogon (Imperata spp.) with some bushes and low trees. Originally the talang was probably entirely covered with tropical high forest. The soil in general was probably not rich, but in the course of centuries in the modest humus layer under that forest all kinds of plant nutrient materials had accumulated. Then in the process of kaiñgin agriculture the forest was cut by the inhabitants. Soon becoming unproductive, the kaiñgins were abandoned and new forest came up, but not so good as the former, because as a result of erosion the good surface soil had naturally for the greater part been lost. Consequently kaiñgining the second time gave poorer results, etc. Now in many places a stage has been reached where no forest at all comes back again and the impoverished soil lies idle.

At this stage, a quarter of a century ago, Hevea came into the picture and that strong rubber boom excellently demonstrated the nature of the talang lands (see Fig. 191, page 542). Being much pleased that Hevea, even on the prospectuses of promoters exhibited a willingness to grow on talang terrains, the inhabitants planted rubber seed everywhere on the talang in Sumatra. And now in general we can see in the rubber trees how much and what sort of volcanic material had been mixed into the soil, for without such material the talang soil promises very little, even for Hevea.[257] Above we have already seen (page 540) that, according to the experience of Bongers, in Siak the trees appeared yellow and miserable. In Djambi the condition of the trees is quite a good deal better. In the Lampongs, where the excellent Krakatau ash has been spread out over the land (see Table 112, page 529), the trees are the best. Although in this region there is not very much native rubber culture, the rubber on European estates in the Lampongs shows these effects distinctly.

In general the soil of the vast expanses of the talang is a senile brownish red lixivium, originating from alluvia and coarse colluvia of the large rivers. In road cuts countless times the senile profile can be seen. This has been described in page 144 ff. and Frontispiece A--(see also Figs. 192, page 544 and 197, page 549). In places, more toward the mountains, it is evident that these coarse river deposits have had the character of lahars. In such regions

257. Regarding this compare the series of reports collected under the title: De Bevolkingsrubbercultuur in Ned. Indië (published by the Dept. v. L. N. en H., 1925-1927).

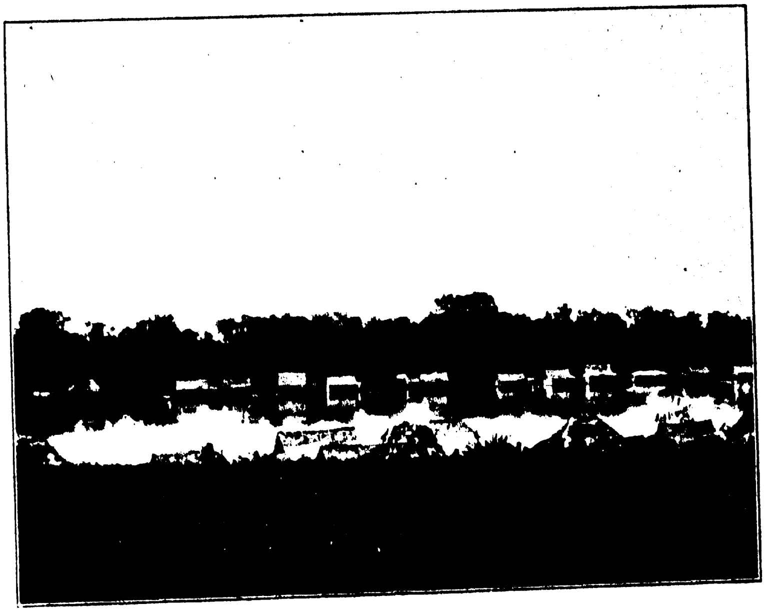

Photo by J. A. van Rijn van Alkemade

Fig. 193. The Djambi River near the main town of Djambi. Houses on piles, at the foot of the natural levees, since here the floods can not rise so very high, because of the nearness to the sea.

there is also more probability that the soil is somewhat less senile. While this may more likely be the case in Palembang and the Lamponga, in Djambi however one need have few illusions that less senile soil can be found.

Returning to the river deposits in the low land of Djambi, it has been ascertained that those along the Batang Hari and the Batang Tabir and the small rivers coming out of the north are not better. Nor does the Batang Tembesi bring much excellent sediment with it. We have already learned of the Merangin in the description of the plateau of Bangko, and the Batang Tembesi and the Batang Asai come out of old, silica-rich mountains, .Hence the fine sand deposits are also very rich in quartz, and beyond Moeara Tembesi the deposits of the Djambi River consist of alluvia becoming continually finer and finer with a high percentage of quartz silt, also white glass which weathers only with difficulty. Along the banks of the rivers in Djambi (see Fig. 193, above) natural levees have also been built up and along the sea shore are slight ridges, while behind them, as farther north, are found shallow swamps, black water, and the formation of peat (see Figs. 194 and 195, page 545).

At the boundary between the subaerial and subaqueous soil formation, at a variable depth, from 1/3 m. to even 2 m. and more, in the soil there is almost always one form or another of iron concretions. In sandy soils these develop into regular solid layers about 20 cm. thick, which simply surround or include the sand grains; in somewhat finer grained deposits the iron concretions begin[258] more as small lumps (krikil), of fantastic form and all sorts of consistencies and colors. The latter for example vary from light yellow through all tints and shades of red to dark bluish violet. In clay and heavy clay

258. These iron concretions sometimes contain quite a good deal of Al_2O_3. In the laboratory of the Commercial Museum section of the Colonial Institute of Amsterdam 11.6% Al_2O_3 was extracted by strong alkali from iron concretions from Djambi.

Photo by J. C. van Eerde

Fig. 194. Palembang. Dwelling on a fresh water creek in the swampy lowland, with the vegetation which is associated with these conditions. (see also page 549)

Photo by Th. Del Prat

Fig. 195. Ajer Kramasan, close to where the Ogan flows into the Moesi, Lebak region, Palembang. Deep brown water. Marsh vegetation.

clay loam they form only round grains: hail ore, bean ore, or blackish brown bean cakes. If other, harder stone material is lacking or is not locally obtainable, the second of the three forms mentioned, which is the hardest, is especially appreciated for road metalling. This is particularly common not only in Djambi but also in Palembang.

It has already been stated above that the somewhat higher lying kasang lands are seldom or never kaiñgined. This statement is not without exception; indeed rice is still planted on this soil, especially where just previously forest stood, that is, on the relatively lower uplands. But this is true even more on the lower forelands, the renah lands, and also on still lower terrains, the pajas or swamp paddies. The last-mentioned lands are however no more true paddies than those in southeastern Borneo. They are not rice fields in permanent cultivation. Thus in common with kaiñgins, they are planted in succession at most a couple of times, then because of inadequate plant food supply the land is again left fallow for some years.

All memoranda of giving over charge by the local administrative officials,[259] who also know other districts of Sumatra and of the Archipelago, agree that the lands of Lower Djambi are poor or bad. They bring out how, near to the coast, first near Kwala Toengkal and later north from Moeara Sabak, plantings of cocos have been made by the Bandjarreezens on the clayey coastal ridge where the palms apparently develop well. Without doubt we can ascribe that success to the fertilizing influence of the sea, an influence which is lacking farther inland. Rattan and jelutong[260] are also limited to the relatively narrow coastal strip. With regard to firewood cutting there is no need of repetition, for what has been said on page 541 also applies here.

Yield figures for the cultivation of rice on kasang, renah and swamp paddy lands of Djambi, I have never found. It is a question whether in this region test cuttings have ever been made for this purpose. Yet they are very necessary, if one is to avoid the suggestive influence of too optimistic expectations[261] or of a priori too pessimistic deductions.

The lower drainage basin of the Djambi river is an agricultural region difficult to maintain in a prosperous condition. Experimental plantings of cotton, coffee, and pepper have come out badly. The farmers usually play two cards, rice and rubber; rice by preference on the low land, rubber on the somewhat higher land. The low land is, however, frequently ravaged by floods. Gobius[262] makes mention of differences in water level at Moeara Tembesi of 10.25 and 10.80 m. between the lowest and highest levels of the river. It is obvious that such floods must mean a failure of the crop. It wouldn't be so bad if the floods brought much fertile sediment onto the fields, but even that is not the case. Thus reforestation especially of the higher mountain regions and the hilly land is indicated for the future. In that way the undesirable fluctuations of the rivers will be reduced and the rice yields, while indeed not high, can be counted upon more regularly.

7. The Drainage Basin of the Moesi

This, the greatest river basin of Sumatra, approximately twice as large as the entire Netherlands, shows distinct differences in its several parts. Naturally differences are more marked in the regions along the upper courses of the different affluents than close to the sea. And also greater than between the upper course regions and their respective middle course

259. There may be mentioned: A. O. Frohwein, Alg. Mem. Onderafd. Djambi (Febr., 1931), pp. 2, 13; G. Ch. Rapp, Alg. Mem. onderafd. Djambi (Nov., 1934), pp. 3, 30. Th. B. van Aalst, Mem. v. Overg. onderafd. Ma. Tambesi (Oct., 1929), pp. 22-25. Here, among other things, it is argued that the yield of rice is inadequate to provide for the needs of the people themselves.

260. Probably Dyera costulata a big tree of tropical lowlands producing a light timber and a useful latex.

261. See especially the writings of earlier dates, for example: W. H. Keuchenius, Bekn. nota afd. Djambi, T. schr. Binn. Best. 43 (1912), p. 259, which express many expectations, which in later times have often been fulfilled on only a very modest scale.

262. O. A. Gobius, Mem. v. Overg. onderafd. Ma. Tembesi (October, 1933), pp. 3, 4.

and lower course terrains.

In the discussion of the South Sumatran Mountains (pages 514-537), the locations have been given where old rocks are exposed at the surface, and where young volcanic efflatas of more acid character are found, along with the basic eruptives of the geologically youngest time. In order to avoid unnecessary repetition, upper river regions there referred to will be left out of consideration here as much as possible, and attention will be especially on the rivers and their sediments.

Originating from the volcanic Boekit Daoen (see pages 518, 535) in Upper Benkoelen, the Moesi flows through a deep valley still well forested, passing among others Tjoeroep and Kepahiang, and on toward Talang Padang, where the Ajer Lintang flows into it. The latter river drains the water from the western part of the Pasemah plateau, and from the plain dominated by Mt. Dempo, the volcano which has blessed this plain with a covering of fertile ash. No wonder that there are many fertile paddies.

Thereafter the Moesi flows through the old Goemai mountains (see pages 514, 531), and what the river obtains from them in no way improves the quality of the water and silt. Below the Goemai Mts., the river enters the hilly land of Tebingtinggi which, pedologically considered, is already high talang. Although Tebingtinggi is but 100 m. above sea level, yet even in a direct line is quite 250 km. from the sea. Here the rivers all flow in quite deep valleys, thus they easily take the erosion products from the land but can't contribute anything to it. And since the talang is deeply weathered to a quite senile stage, from this high talang the Moesi receives only worthless senile erosion products.

First near Moeara Klingi the Moesi becomes a river in a low plain,[263] as does the Rhine, shortly before it enters our Holland. There the Moesi receives reinforcement from the Ajer Klingi. This great tributary river also comes of a quite good family, at least originally, where it takes in the water and silt from the volcanoes Boekit Kaba and Boekit Kelam. Its tributary river, the Ajer Beliti, is somewhat less good but still tolerably so, as the surroundings of Moeara Beliti clearly indicate. Already from Moeara Klingi on, in the time of floods the water of the Moesi flows out everywhere over the banks. Thus there begin the deposits, although even there some water flows from the talang into the river (see Fig. 9, p. 130).

Farther on the Ajer Rawas unites with the Moesi. The Ajer Rawas comes from the Djambi boundary. As its important tributary it receives the Ajer Roepit, the water of which is from old rocks: sandstones, claystones, limestones and old volcanic formations, which in part are rather strongly acid (i.e. high in silica). Neither the one thing nor the other is any recommendation. For that matter the map of population density of Sumatra shows this very well, as we shall mention again further on (see page 551). But it is also observable directly on the ground; for near Moeara Roepit where the two rivers reach the lowland, they overflow and spread their sediment out covering the land, and that sediment is a pale yellowish gray loam in which there is much extremely fine quartz silt, which seals over the soil but in no sense increases the fertility. Especially these deposits of the Ajer Roepit could be called an excellent pottery clay, but this material does not now have any value for pottery, nor will it have until the region in which it lies has attained a sufficient density of population and such a level of culture that a pottery industry could be built up there.

At Sekajoe the Moesi then leaves the low land, which at times during low water is exposed above the water, and flows out into the land of permanent swamps. Sometimes the water flows out of the swamps into the lower river, while at other times the flow is in the opposite direction. When the Moesi is at a somewhat low level the swamp water is generally clear and brown (ajer hitam) and from a boat depths of sometimes 8 m. and more can be sounded, hence it is easy to understand why the deep water appears to be black.(see Fig. 195). In this sort of terrain not much soil is to be seen. What is dredged up from below is naturally gray to grayish white,

263. See: J. van Tubergen, Versl. irrig. onderz. Sumatra, Versl. B. O. W. (1913), V, B, (1914-1916), p. 120 ff.

Photo by W. Van Wessen

Fig. 196. Road between Lahat and Pageralam, Palembang. Forelands (renah lands) produce good crops of paddy along the Ajer Lematang.

completely leached out subaqueously, and mixed only with organic matter. Even so, peat is not to be found everywhere, the swamps thus differing from the conditions more to the north on the east coast of Sumatra.[264] Possibly this absence of peat is due to the young volcanic material that the Moesi carried out along with the sterile, base-free sediment. The pH of these swamps has not been low long enough to permit any considerable peat formation, such as has permitted the development of distinct peat lenses farther north. In middle Tertiary time it was otherwise. Relics from that age in Palembang are many former peat layers now converted to lignite. But then volcanism in the hinterland was still not as active as it became later.

After the brief remark that the Moesi takes in the Batang Hari Leko as the last important tributary river from the north, a river which, with all of its affluents, comes out of the talang hilly land and so it also has only a diluting effect upon the quality of the Moesi water, we may now give somewhat more attention to the great tributary rivers coming from the southwest.

There is first the Ajer Lematang with its most important tributary river the Ajer Enim. Both are of significantly better "standing" than the Lower Moesi. They come out of the eastern part of the Pasemah, the plain of Pagar Alam and Bandar and the mountains lying east therefrom, consisting of a number of volcanoes which surround the Semendo. These volcanoes are indeed no longer young, but they are of good rocks, tolerably basic. As soon as these rivers come out into country which is low enough, they begin to form forelands, renah lands (see Fig. 196 above). These renah soils are generally put under cultivation for rice and a number of other crops. But when beyond Moeara Enim the Lematang becomes a river of the low plain, very soon there are no more true renah lands. Further on down the river the inhabitants live particularly on the natural levees along the banks which

264. Compare: F. W. Endert, Woudboomflora van Palembang, Tectona XIII (1920), p. 113. At that time not so much attention was being paid to pH determinations as is now the case twenty years later.

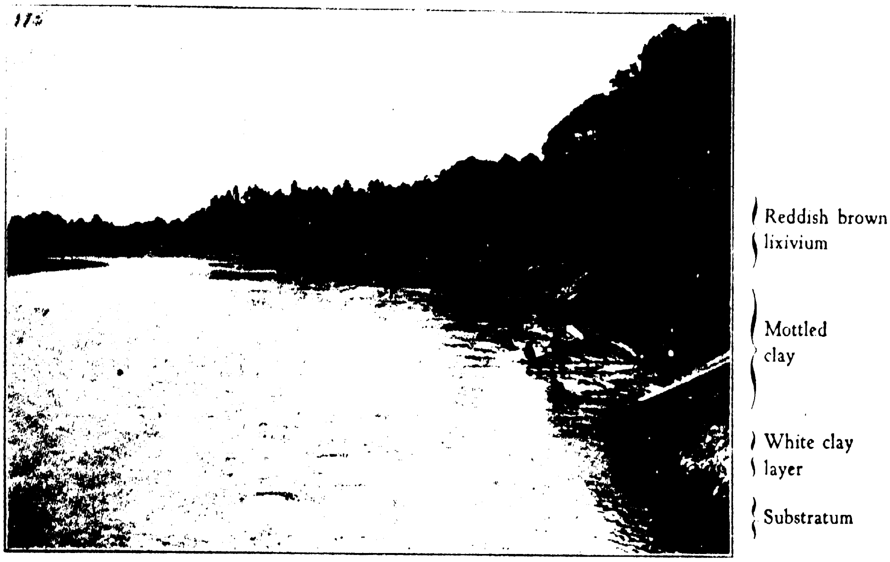

Fig. 197. The Ajer Lematang at Moeara Enim, Palembang. Many bananas, cocos and fruit trees along the river. The river bank shows the soil profile described on p. 184 ff., and figured in Frontispiece A. The less rapidly eroded projecting white clay layer can be seen.

are also called renah.[265] On these the natives plant coco and other trees which can tolerate a high water table during the frequent floods. They also plant crops which can come to maturity in a few months on upland soil (in the dry season). The people living along the banks of this river are mostly dependent upon the river itself for their support (see Fig. 197 above).

The Ajer Ogan and the Ajer Komering are also important tributaries, and in some degree different in origin. As to that, the Ajer Ogan resembles somewhat more the Ajer Enim. While the Ajer Komering originally receives much from the "surroundings of lake Ranau which are covered over with more acid tuff." In the middle course this can still be recognized in the many quartz crystals and pale bits of glass and pumice stone which have been deposited by the Ajer Komering on its renah lands. Because of this the Komering deposits are here poorer in quality than those of the Ogan.

The low swamp land[266] receives relatively little benefit from these two rivers, although locally indeed it does receive a good deal, especially on the natural levees along the stream banks. And also on those places where the inhabitants can plant rice on the deeper lying, low portions (see Fig. 194), in so far as they are enclosed by natural levees, supplemented by small portions of artificial diking. Similarly, toward the interior, on the weakly sloping lands which in the rainy season are completely submerged and so form a lake, but which in the dry season gradually dry up[267] from the edges out toward the deepest point; in Palembang such lands are called lebaks. If these lands are planted in time and the growing

265. Cf.: J. Szemian, Aanteek, agrogeol. verk. reis Palembang, Bergcult., IV (1930), p. 79-81.

266. It is indeed striking that Endert (l. c.), on the map he sketched, did not indicate any peat swamp forests in the low regions along the Ogan and Komering, except in the last portion of the regions of these streams; also that he did not show any along the Lematang. On the other hand he did show peat swamp forests along the Moesi and the A. Rawas, even up close to the mountains.

267. This "dry season" is as a rule but relative and moreover cannot be counted upon. It is to be kept in mind that while as to the climate this region is still indeed in group VI (Table 94, page 424) yet it is approaching group V (Table 94, page 424).

and ripening of the rice keeps pace with the gradual evaporation, then large yields are obtained, indeed to as much as 52 quintals rough rice per hectare, although the average is approximately 26 qu./ha. If the rains fall too early, then the rice is drowned and the crop is a failure.

High diking and technical regulation with sluices, so that by letting water on and draining it off, keeping the level entirely under control, would in the future be very useful for the lebaks along the Lematang, Ogan and Komering. This is true because even in the time of the submergence of the land these rivers should bring good water and good sediment onto it. The Moesi also forms lebaks, but not of such good quality, and upstream from the junction with the Ajer Lematang practically no benefit can be expected.

The striking excellence of the yields of crops planted on these low flooded lands (lebaks) is apparent if we consider that such land produces on the average approximately 17 quintals per hectare, while from kaiñgins on talang only 10 qu./ha. have been recorded.[268]

A paradoxically sounding remark by the district civil officer Dirks[269] deserves to be mentioned here: "These are the very villages which, as shown by the list of the density of the population, are in the most thinly populated regions, yet they complain of the lack of land!" This reference is obviously to lack of land they can cultivate with profit. Already there is more than enough useless land.

As to this it may also be stated that the Agricultural Extension Service reports[270] that "on fertile alluvial (renah) lands along the Enim it is not uncommon to obtain 35 quintals dry (upland) paddy per hectare." However there are but 4 to 5 plantings in succession and then the land is allowed to lie idle for a considerable number of years. On talang lands on the other hand, the yields of upland rice vary from 9 to a maximum of 17 quintals per hectare, and fields on these lands are abandoned after only one harvest, and are usually not planted sooner than 5 to 7 years later, though sometimes again as soon as 3 years.[271] "For a few villages in one of the higher lying coffee districts the Agricultural Adviser estimated that with an average farm of 11 hectares of the variable soils, the native farmer employing kaiñgin agriculture and thereafter on the same land planting coffee which only yields for a few years, does not produce more than 13 to 17 quintals rough rice and 7 quintals coffee per year." This quotation[272] indicates something of the relative poverty of the higher talang or lower mountain districts of the region.

Characteristic of this situation is the following statement regarding this coffee cultivation:[273] "The lands planted to coffee in the uplands of Palembang for the greater part consist of very much broken and rough country. Almost the only lands used for coffee are those covered with heavy forest, since cultivation of coffee is really satisfactory only on humous forest lands.[274] It is therefore to be regretted that no attention is paid to the maintenance of the soil capital. Ordinarily after 8 to 9 years the soil of a coffee garden is exhausted, after that it is abandoned and allowed to lapse again into the Public Lands. From the pedological standpoint, however, the soil has deteriorated since no fertilizer in any form is ever applied. The growing of coffee is only possible because the native planter is skilful in selecting the very best lands and limiting the crop to those. But even this expression "the very best" must still be taken with a grain of salt; the cultivators adjust themselves to get along and be satisfied with a low minimum rate of return. On the "less good" lands the yield amounts to approximately 1 3/4 quintals per hectare. On the "better," yields of from 4.5 to 7 qu./ ha. are obtained, while a few unusually excellent gardens give as much as

268. A. Dirks, Aanv. Mem. v. Overg. onderafd. Ogan Ilir (1933), pp. 27-30.
269. L. c., p. 41.
270. Versl. Lb. Voorl. dienst (1913), p. 209.
271. J. Tideman, Mem. v. Overg. Residentie Palembang (1928), p. 245.
272. Tideman, l. c., p. 245.
273. Tideman, l. c., pp. 258-259.
274. Compare in this connection what has been said on pp. 475-476 above regarding forest humus.

17 to 18 qu./ha. About the fifth year the planting gives its highest yield, thereafter the production rapidly declines." This lengthy quotation is indeed very significant regarding the rapid exhaustion and the loss of the humous soil, lying on a senile, poor subsoil. It is not difficult to picture what great good fortune for the impoverished talang regions has been the cultivation of Hevea rubber trees which make such modest demands upon the soil. So it was that in 1928 Tideman[275] wrote: "At present it may be said that the cultivation of rubber is the native cultivation of the talang plain."

How far even the Semendo region paddies, which are called excellent, still fall short of an ideal fertility has been shown by the fertilizer experiments of the Agricultural Extension Service.[276] While unfertilized fields produced but 17 quintals per ha., by adding 1 3/4 qu./ha. double superphosphate there were obtained 45 quintals paddy per ha. Here a marked deficiency in P was strikingly demonstrated; since that time the natives have annually applied great quantities of double superphosphate.

Finally, let us briefly consider the density of the population[277] as a function of the nature of the soil. Thinly populated are the river tracts of the Ajer Rawas and Ajer Roepit (about 6 souls per km.^{2}) and similarly those of the Ajer Klingi and Central Moesi (also about 6). Along the upper Moesi (Lebong) there are more people (14), but in the Redjang still more (23). Tebingtinggi, to which also the western part of the Pasemah high plain belongs, has an average of (21), but the rest of this plain, with the Dempo volcano brings it up to (37). Next to these Lematang-oeloe has (24) and Lematang-ilir (26), Ogan-oeloe (19), Moeararadoewa (18), Komering-oeloe (14), while Ogan-ilir with the lebaks (35). Thereafter we come into the low swamps: Komering-ilir with but (6), and in the north the extensive region of the Banjoeasin and Koeboe tracts with about (3) inhabitants per km.^{2} A glance at the map makes it very clear that the Lematang and the Ogan have the most fertile drainage basins and so the densest population.

8-10. The Drainage Basins of the Way Toelangbawang, the Way Sepoetih, and the Way Sekampong Rivers

Between the drainage basins of the Moesi and the Way Toelangbawang there is also an extensive, low part of Sumatra, wherein are a number of smaller and larger rivers. The largest of these is the Soengei Mesoedji, for a large part the boundary between Palembang and the Lampongs.

This low land has a character all its own, as is evident from the publications of Van Tuyn.[278]

The present conception of the physiographic development of this region is that after the formation of the great peneplain of East Sumatra there occurred a rising of the land and/or sinking of the sea level. The consequence was a period of erosion wherein were cut down deep river valleys which became continually broader toward their mouths. At that time the dry land included what are now the Java sea and a large part of the South China Sea. Following this there was a transgression of the sea, during which the Java sea came into existence, while along the eastern side of Sumatra many river valleys were partially drowned and became arms of the sea. In these from that time on marine clay began to settle out and accumulate. Along most portions of the land remaining dry between the river valleys and facing the open sea the surf formed steep cliffs while elsewhere the pounding of the surf and the steady winds threw up barrier beaches.

After this there was once again a slight elevation of the land, not along the whole of the east coast, but especially along this part. This elevation was enough to raise a large part of the youngest marine

275. Tideman, l. c., p. 249.
276. Versl. Landb. voorl. dienst (1919), pp. 328-329.
277. Census 1930, IV, Inh. bevolk, Sum., Table 9 and map.
278. I. J. van Tuyn, Toel. bij blad 13 (Wiralaga) o/d Geol. Krt. Sumatra (Bandoeng, 1934), pp. 6-13. II. Idem, Toel. bij blad 8 (Menggala) (Bandoeng, 1934), pp. 7-9. Both publications have very clear and striking photographs.

deposits in the river valleys, so that at least now and then they were dry. Pieces of talang, previously islands, which had been nibbled at by the sea from all sides, now lie as higher portions in the center of the lower marine clay marsh lands.

The peneplain, mentioned above, was at this time far from senile, but for a great part in just this region and its hinterland consisted of "Middle and Upper-Palembang layers," that is to say, of the acid tuff, sandstones and pumice stone tuffs, alternating with claystones. It is true that this material, at present noticeably further weathered, is still to be found in these places. And in the low, marshy land we cannot expect that any pronounced peat formation has occurred.[279] The surface soil is indeed black, with a gray subsoil, but it cannot be called peat.

While we may safely presume that here earlier the land was occupied by an endless tropical high forest, it no longer exists. Along the coast and along the great rivers there is a tidal zone, at most a few kilometers broad, in which the marine clay flocculates out and precipitates in the sea water or in the brackish water. Along the edge of the sea is a strip of mangroves and inside of that one of nipah "palms." Further up along the rivers are many pandans. Behind this zone there lies the extensive swamp region. That is, a region which is more or less dry in the dry season (this part of Southeastern Sumatra is already within the sphere of influence of the east monsoon!), but in the rainy season the soil is submerged to about a meter depth. There is no forest on this land; at most, a few trees which can well stand the great seasonal differences. There are endless open "lebaks" which have only a grass vegetation. At an intermediate elevation between these and the talang forest, which is just as poor in timber as is the vegetation of the talang regions lying more to the northwest, lies a strip of varying width with swamp forest, in which is an abundance of rattan and swamp palms. In this swamp is found true "ajer hitam" and also clay soil rich in plant remains, but still no peat.

The sparse population of this region has its huts on the natural levees and around the talang islands. There are no roads; the only means of transportation is by water. At present, seeing that the various soils are hardly used at all, there is apparently not much appreciation of the value of the different soil formations. An optimistic look into the future would seem to expect perhaps some possibilities in the high portions of the strips of marine clay along the rivers, sticking like fingers into the land, presuming, of course, that the regulation of the water on them can be gotten into hand.

* * * * *

Much of what has been said above also applies to the drainage basin of the Way Toelangbawang, as well as to the lower courses of the Way Sepoetih and its tributary river, the Way Teroesan. This can best be seen on the above, already referred-to, sheets 13, 8, and 4 of the new Geological Map of Sumatra on the scale of 1:200,000.

However, the farther south one goes, the older the Quaternary tuff becomes, also the more the predominantly tuffaceous layers are buried, and on many spots there is also a gravel covering. This is the tuff which was mentioned in the previous chapter (page 521 ff.). Toward the southwest the size of the gravel increases. This is the direction in which the granite gravel region lies, and shows the relationship with it, or rather through its petrographic nature we know that it originated from that. Along this zone the gravel consists almost entirely of these rocks, which are not young volcanic.

Now as to the soil: The drainage basin of the Way Toelangbawang begins with that of the Way Giham, the Way Oempoe and the Way Besai, coming out of the mountains, and described on pages 521 and 536. As these rivers and a number more to and including the Way Rarem, come into the lowland they first flow through hilly land lying at 150-50 m. elevation and then through a somewhat lower talang tract, the so-called "Rebang district." This has, however, a much better reputation than the talang in general. Sheet 5 of the

279. Van Tuyn, l. c., I, pp. 9, 24. Here and there it is true one comes upon heaving due to pressure.

Geological Map (Kotaboemi) explains why: the Rebang district is given the color of "andesitic volcanoes and tuff mantles"; the railway line from Kotaboemi nearly to Gedongbatin runs approximately on the boundary between this and the lower and different terrain which on this map is designated as "Quaternary river sediments and acid tuffs of the plain." Perhaps through many good and bitter experiences the natives of Rebang have found where they ought to settle, and where they must not. If the geological map be compared with the topographic one, it is at once apparent how much thicker the settlements are on the andesitic, than on the acid tuff covering. And in the field when passing from sandy, pale red lixivium onto a warm red, quartz-free lixivium it is likewise apparent. One goes from a miserable talang vegetation into a stretch with many villages, bamboo, fruit trees, and planted crops. This stretch, however, does not extend out nearly so far as do the acid tuffs which extend out too close to the mouth of the Toelangbawang. But the Rebang is not yet thickly inhabited, and more new residents should be able to settle there; especially if all the area which is irrigable in that andesitic region were well irrigated. At present however, there is not a bit of modern irrigation in that whole region.[280]

Also the rivers Way Pengeoboean, the W. Sepoetih, and the Way Sekampoeng come originally out of the mountains in the western part of the Lampongs, then flow on enormous distances through the flat, acid tuff talang-like region, which for a great part is still extremely sparsely inhabited. The region between the basins of the W. Sepoetih and W. Sekampoeng is drained by the W. Pegadoengan. Since this river neither rises in nor flows through mountains, but only comes out of the acid tuffs, it transports a fair amount of quartz sand. No wonder that at its (earlier) mouth it threw up a broad sand bank[281] from behind which, after the slight elevation of the land which was mentioned on page 537, it was forced to hunt a way out northwards and so to empty into the Sepoetih just before the latter flows into the sea.

The Way Sekampoeng originally must also have flowed from the southwest toward the northeast. But at present, however, because of the formation of the basalt cake of Soekadana in that region, it had to find a new way out and in so doing turned toward the southeast. The bay to the south of the "island of Soekadana" was perhaps once the outlet of this river but, as the sea developed a barrier along the present-day coastline on the outside clayey, and gray on the inside flanked by gray or yellow sand, to this degree the arm of the sea was altered into a lake. It was really a swamp, which simultaneously grew thick with peat and filled up with sediment, so that the mouth of the Sekampoeng river now lies southeast of the southern point of the basalt cake, and at a considerable distance from there. But the swamp is still so much of a swamp (Rawah Sragi) that even today this region is uninhabited.

Finally--a brief consideration of the density of the population, since only the figures of the larger subdivisions are at hand. The highest figure (38 souls per km.^{2}) is that of Telok Betong which was the subdivision of the whole residency which was most seriously "ravaged" by the Krakatau explosion in 1883. Then follows Kota Agoeng (15), with the still young volcano Goenoeng Tanggamoes and the Semangka valley. There follows Kotaboemi (13) with the Rebang, but also much acid tuff talang and also some andesitic highland. Finally Menggala (5.6) and Soekadana (5.9) with a talang of especially acid tuffs.

Among the most important native crops we find pepper, especially in the Telok Betong subdivision and also in the Rebang, while a large part of the coffee is grown in the Kotaboemi subdivision.[282] A large proportion of the rubber estates also lie in the first-mentioned subdivision; in other words the export crops are concentrated on the andesitic lands, to which we can add pepper on the basaltic island of Soekadana! Paddy rice, properly irrigated, is still principally confined to the Way Lima, where the lands of the

280. F. J. Junius, Alg. Mem. Res. Lamp. Distr., (Mei, 1933), pp. 145-152.

281. See the repeatedly referred to sheets 8 and 13 of the Geological Map of Sumatra.

282. See Junius, l. c., p. 43.

Javanese Colony Gedongtataän have been blessed with Krakatau ash, in fact, doubly blessed, first by the ash which fell from the air, and secondly by the ash washed off northwards from the Goenoeng Ratai mountains onto the lower lands.

Already in the previous chapter (page 533) the contemplated irrigation was mentioned as the basis of a new Gedongdalem colonization. The terrain lies entirely on the acid tuff talang between Goenoeng Soegih and Soekadana, while the water will come from the talang rivers. According to my opinion, which may be deduced from the previous pages, there must indeed be very urgent reasons why the Rebang and in a broader sense the andesitic land has been allowed to lie without irrigation and yet an irrigation experiment is undertaken on a large scale on the acid tuffs. It is possible that the experimenters have proceeded from this standpoint: if the test experiment succeeds, then enormous perspectives open. That was also the point of departure for the test clearing at Selatdjaran in the Moesi delta. Though this latter did not succeed; a priori Gedongdalem promises more and better. But even although it will be a great and continuous success, one should still be careful that with regard to irrigation no injustice is done to such tracts as the Rebang.

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JAVA

INTRODUCTION

In order to obviate any misunderstanding my premise should be stated at once, namely, that in what follows it is in no sense my intention to discuss exhaustively the soils of Java; this is not a monograph which is intended to stand independent of the preceding parts of this book. On the contrary, in the following discussion Java is properly considered as a portion of the Netherlands Indies, and therefore the soils of Java--and Madoera, which obviously belongs with Java--are treated as a part of the soils of the Netherlands Indies as a whole. In order that the relationships of the whole may be as clear as possible, special emphasis will naturally be placed upon the particular points of agreement and difference with other portions of the Indies.

It is quite in order to point out the fact that Java, because of the advanced stage of agriculture and because of its density of population, and because of its importance in relation to the other islands, occupies a special position, and that also with respect to the soil significantly more is known of Java than of the other parts of the Archipelago. Yet at the same time we must also remark that upon closer examination this more extensive knowledge is really more quantitative than qualitative. It is indeed true that for Java we have available an extensive net of observations and experience as to yields of many kinds of crops as well as the results of fertilizer and other crop tests. We also have extensive data relating to the climate and the nature of the soils. Even so, these data are still not of such a nature that even for Java we can get a deeper insight into soil characteristics, soil formation and soil alterations than we have been able to get for the other islands of the Archipelago.

The Soil-Forming Rocks of Java

As has been demonstrated repeatedly in the first part of this book, the petrography of Java has even greater hiatuses than, for example, that of Sumatra. It is true that there is a geological map with accompanying descriptions covering all of Java and Madoera,[1] and although for its time it was a work of the highest merit, it is already more than 40 years old, so that naturally in certain respects the data are now out of date. Particularly for use in connection with soil science the classification is entirely too general. For example, when we find that all the volcanic rocks and their segregation forms are included under one color (rose), marked "V" (= volcanic), then it is at once evident that there is no need for us to discuss this point farther.

More recent times and newer points of view demand much finer petrographic differentiations. The purpose of the new geological map indicates this clearly.[2] For example, on sheet 36 (Bandoeng), one of the two sheets which have thus far appeared, for volcanic formations there are 9 differentiations shown by colors and symbols, while on the map of Verbeek and Fennema these were all under the one color. If the reader remembers the striking significance of Druif's differentiations of the different mud flows,[3] for the Deli tobacco cultivation on Sumatra's East Coast he will at once realize the great significance of the thorough-going differentiations which the new map of Java has, both for soil differentiations, and for the opening up of new points of view concerning all kinds of important crops, both those raised by the natives as well as by the Europeans.

It is indeed a pity that thus far (1937) still only 7 of the projected 148 sheets have appeared. Because of the

1. R. D. M. Verbeek and R. Fennema, Geol. Beschr. v. Java en Madoera, with Atlas (Amsterdam, 1896).
2. A. C. de Jongh, Toel. bij het schema eener algem. geol. legenda voor Ned.-Indië, Jb. Mijnw. N. I. (1930), Verh. III, p. 56.
3. This book, pp. 464, 468-472.

circumstances of the time, this work for the results of which so many Government Services, as well as private parties wait, and was even entirely suspended for quite a time has now finally been resumed upon a modest scale.

Although we can only hope that in this work a change for the good may rapidly come about, for the preparation of this book the few maps with descriptions which have appeared can help us only relatively little.

For more than a half century mining engineers and geologists have studied intensively the rocks of the Netherlands Indies. The main line of study of the massive, igneous, and metamorphic rocks has been in the field of petrography, but during about the last decade more petro-chemical studies have also been made. The sedimentary rocks have been studied especially paleontologically, and to a less extent petrographically. This field is known to be of service, and as already mentioned on page 522 of this book, in the last few years a first beginning has made in sedimentary petrography. Even so, complete chemical analyses of sedimentary rocks of the Netherlands Indies are still as scarce as they were many years ago. From geological or mining-engineering points of view doubtless not much is to be gained from analyzing sedimentary rocks, although from the soil science or agricultural points of view such analyses would almost certainly be of very much value. As an example of the meagre data with which one must be sometimes content, I may mention that in 1932 while studying the soils of the Principalities, Tollenaar[4] attempted to differentiate two types derived from two different limestones, about which he could only say that the one was "very pure limestone," while the other was "quite pure limestone." To illustrate how unimportant sedimentary rocks have been considered to be, it may be stated that of 181 published rock analyses made by the Petrochemical Laboratory[5] at Bandoeng, but 5 are of sedimentary rocks and, since the constituents important for soil science, K, Na, Mn and P have not been determined, even these 5 rocks have been analyzed only incompletely.[6]

Consequently, practically nothing of importance can be recorded concerning the chemical composition of sedimentary rocks of Java for the study of the soil. With reference to the eruptive rocks, in particular the lavas and the various kinds of volcanic ash, more data exist. To supplement the analyses which have already been given in the first part of this book, Table 115, page 560, has been included.

Considering all of the data we come to the conclusion that, except for a few exceptions to be noted later, the analyses of the volcanic rocks of Java, whether these are selected from those in West Java, Central Java, or East Java, do not differ much more among themselves than the analyses of different products of one and the same volcano. From no other single volcano on Java are there available so many analyses as of samples from the Slamat,[7] namely 18 (if one does not include the specimens marked "weathered"). Of these 18 the analyses of 7 are given in Table 20; the data of 11 more are to be found in the folding Table 115, page 560. In order to facilitate the comparisons I have given in Table 113, page 557, somewhat rounded figures of the averages, the maxima and the minima of the analyses of the Slamat samples, and beside them rounded averages and extremes of the analyses of samples from other volcanoes, which fall outside the extremes of the Slamat figures (see Table 113, page 557).

From these data it is evident that the different rock forms of the Slamat, at least chemically, include as good as all the forms of rocks which other volcanoes of Java, from West Java to and including East Java, appear to have erupted. It is by no means unlikely that with an equally detailed analytical study other volcanoes or volcanic complexes such as, for example, the Gedeh in West Java or the Diëng mountains, the Tengger complex or the Idjen mountains, would give an equally wide range of values for the various elements--a range as great as for all Java.

Upon closer study the following

4. D. Tollenaar, Meded. Proefst. Vorstenl. Tabak, No. 73 (1932), p. 29.
5. See: Jb. Mijnw. Ned.-Indië, (1930, 1931, 1932-33, and 1934-35).
6. L. c., (1930), p. 252
7. See: Jb. Mijnw. N. O. I., No. 44-66, (1930), pp. 258-262.

Table 113

Analyses of Volcanic Rocks

	Slamat Volcano			Other Volcanoes of Java		
	Minimum	Average	Maximum	Minimum	Average	Maximum
	%	%	%	%	%	%
SiO_2	49.0	52.8	58.7	47.2	54.2	62.9
Al_2O_3	16.1	18.2	20.4	12.1	18.1	20.6
Fe_2O_3	1.2	3.7	7.4	1.2	4.3	10.6
FeO	2.6	5.1	6.7	1.4	4.1	7.8
MnO	0.1	0.13	0.2	0.1	0.18	0.3
MgO	2.3	4.2	5.9	1.2	3.4	8.5
CaO	6.9	8.1	9.6	4.4	8.2	13.5
Na_2O	2.9	3.4	3.7	0.7	3.2	4.3
K_2O	1.0	1.5	2.0	0.3	1.8[1]	3.6[1]
TiO_2	1.1	1.7	2.5	0.3	0.85	2.5
P_2O_5	0.2	0.36	0.7	tr	0.25	1.6

1. If one includes the analyses of the calcium-rich leucite rocks, then the maximum becomes 6.7 and the average 2.2. For that matter the entire table is not free from accidents and arbitrary treatment, and consequently is only a rough approximation.

relationships of the constituents appear: The silica figures indicate that the Javanese volcanic rocks belong with the basic effusive rocks (basalts, hypersthene-andesites, etc.) to intermediate rocks (hypersthene, augite, little hornblende, still less mica-andesites). Acid rocks, with amounts of silica higher than 63% are not among the compact rocks or lava streams which have thus far been analyzed; nor have there been analyzed any ultrabasic rocks with less than 45% SiO_2.[8]

The Al_2O_3 content varies but little; most of the figures lie between 17 and 19%. Only a few rocks of the Papandajan, the Slamat, Diëng, etc. are higher than 20%, and but few rocks of the Slamat, Diëng, Kloet, Merapi (Idjen) and Ringgit have amounts of Al_2O_3 significantly less than these limits.

Fe_2O_3 shows greater variations, between $1\frac{1}{4}$ and $7\frac{1}{2}$%; while one sample of a basalt rich in iron has more than 10%. FeO also varies a great deal, from $1\frac{1}{2}$ to almost 8%. If only the separation could be made, it would be important for soil science to know what part of the Fe_2O_3 exists as magnetite and what part as ilmenite (titanium iron ore), because under the weathering conditions which produce brown and red lixivia and which are so widely prevalent on Java, these two minerals in the form of the well known "black magnetic iron sand" remain practically unaltered in the soil. On the contrary the rest of the iron in the rocks, present in the pyroxenes, hornblende, olivine, and mica, under the weathering referred to, is liberated at the beginning as colloidal iron dioxide and as such exerts a great influence upon the characteristics of the soil. Now this easily weathered iron is for the most part present in the last-mentioned original minerals as FeO, and consequently the Fe_2O_3 is for the most part to be found as magnetite, but still it is not admissible to accept that the Fe_2O_3 is present exclusively as magnetite. For example some analyses besides the Fe_2O_3 found have too little FeO; such samples are No. 48 from the Slamat and No. 4090 from the Diëng. Consequently on the basis only of the total chemical analysis, it is not possible to

8. R. van Bemmelen did indeed publish analyses of ultra-basic rocks in: De Ingenieur in N. I. (1937), IV, p. 134, but the relatively very small rock masses which these samples represent are without significance for soil formation.

split up the iron into the portions FeO and Fe_2O_3, one of which is important for and the other unimportant for soil science. And while sometimes one cannot do much with rocks very rich in glass, the microscope really ought to be used to make at least a few quantitative countings of minerals to establish the relationships. It would be still better to carry out quantitative mineralogical separations upon crushed samples or rocks, and then make chemical analyses of the separated minerals (see pages 23-25).

Manganese occurs in all rocks in small quantities of about the same order.

With reference to Mg, Ca, Na, and K, while most of the volcanoes are also quite within the limits established by the Slamat, there are still a few striking exceptions. Thus the rocks of the Tangkoeban Prahoe contain but little Mg, yet they have relatively much K, in those of the Galoenggoeng and the Tjerimai there is more Mg and relatively little K. The analyses of the Merapi products (Central Java) somewhat resemble those of the Tangkoeban Prahoe in that they have a plentiful supply of K (an advantage for the cultivation of tobacco!). On the contrary the olivine basalt of the Lamongan which has been investigated has again more Mg and little K. This rock is striking, however, because of its high content of Ca, which is also the case with a number of other basalts (Kloet, Slamat, Galoenggoeng, Goentoer). A couple of Diëng rock samples contain relatively little Ca but the minimum is still 4.38%. Young volcanic soils are thus not likely to be deficient in calcium.

The sodium content is the least variable; almost all quantities are between $2\frac{1}{2}$ and 4%. There will of course be differences between the diverse rocks as to the form in which the Na is combined; as a rule most of it will be found in the plagioclases, but some also occurs in the amphiboles and pyroxenes. However, without separate anlyses of the minerals of which the rocks are made up it is not proper to go into this question. As to potassium, which is so important for plant growth, some points have already been mentioned. It may also be added here that the Galoenggoeng rocks have unusually low quantities of K; nor does the Goentoer appear to be rich in this element. But in agreement with what was stated about calcium, juvenile volcanic soils on Java will supply quite enough K for most plants and crops.

In the Slamat rocks titanium reaches a maximum. Most of the other volcanoes have products with somewhat under 1%. The only rocks with significantly lower amounts are one sample of andesite of the Papandajan and one basalt of the Kloet. In the case of the Slamat the phosphorus content is also high (0.2-0.7% P_2O_5); and tolerably high in the case of the Merapi (Principalities, Eastern Central Java), 0.3-0.4%.[9] Phosphorus is especially low in the rocks of the Goentoer and the Galoenggoeng. It is also low in samples from the Kloet and the Merapi (Idjen, Eastern Java). It is a pity that the analyses of Smeroe and Lamongen rocks do not include this element.

It is evident that the leucite rocks of the Moeriah[10] contain much higher amounts of K than any of the other volcanic rocks referred to above. But also the P content of rocks from this volcano is much higher than that of any of the other rocks referred to. The leucite rocks of the Goenoeng Ringgit[11] and of the Goenoeng Loeroes, lying west from Pamanoekan, are closely related in composition to those of the Moeriah.

In connection with what has been said above (pages 92-95) relating to weathering, now let us consider a couple of analyses by Reiber[12] of "strongly weathered, volcanic rocks of the Slamat." Here they are compared with the averages of the 18 analyses of unweathered, or almost unweathered rocks of the same volcano. This comparison is, of course, not entirely fair for it is only approximate, still it is without any subjective bias to which might be ascribed a certain arbitrariness. On the contrary, it is necessary to make a comparatively arbitrary choice as to the constituent which is considered to be neither leached out nor carried down deeper into the soil profile as a result of the

9. Compare: G. L. L. Kemmerling, Valkanol. Meded., 3 (1921), p. 15.
10. See: p. 38.
11. See: Jaarb. Mijnw. in N. Indië (1932/1933), pp. 80-81, 88-89 (1935).
12. See: Jaarb. Mijnw. N. Indië (1930), Alg. Ged., pp. 258-262.

weathering; in this case Al_2O_3 is taken for this purpose. This is the basis for the following Table 114:

However, as long as there are no analyses of precisely the same rock, both unweathered and weathered, which can be

Table 114

ROCK ANALYSES FROM THE SLAMAT, CENTRAL JAVA

Constituents	Unweathered Rock, Average of 18 Analyses, Nos. 47-64	"STRONGLY WEATHERED" Volcanic Rock: No. 46, Analysis by Reiber	No. 46, Recalculation of (b) on Al_2O_3 of (a)	No. 46, (c) in % of (a)	No. 44, Analysis by Reiber	No. 44, Recalculation of (e) on Al_2O_3 of (a)	No. 44, (f) in % of (a)
Column	(a)	(b)	(c)	(d)	(e)	(f)	(g)
	%	%	%	%	%	%	%
SiO_2	52.76	44.82	35.76	70	34.24	22.46	43
Al_2O_3	18.17	22.76	18.17	100	27.72	18.17	100
Fe_2O_3	3.66	7.71	6.15	168	10.65	6.98	191
Total Fe, as Fe_2O_3	(9.30)	(11.22)	(8.95)	(96)	(13.52)	(8.86)	(95)
FeO	5.08	3.16	2.52	50	2.58	1.69	33
MgO	4.21	4.04	3.22	76	3.45	2.26	53
CaO	8.11	5.30	4.23	52	2.58	1.69	21
Na_2O	3.40	2.63	2.10	62	0.76	0.50	15
K_2O	1.51	0.67	0.53	35	0.28	0.18	12
H_2O +	0.75	5.13	4.09	545	8.10	5.31	708
H_2O -	0.49	1.34	1.07	218	7.02	4.60	940
TiO_2	1.68	1.97	1.57	93	2.47	1.62	96
P_2O_5	0.36	0.67	0.53	147	0.12	0.08	22
MnO	0.13	0.15	0.12	92	0.19	0.125	96
	100.31	100.35	80.06	80	100.16	65.66	66

It is evident that rock 44 has been weathered more than rock 46, and that in complete agreement with earlier results and conclusions drawn from them, both analyses demonstrate:

1. That Al, Ti and Mn, as well as iron, remain; while FeO goes over into Fe_2O_3;
2. That K, Na and Ca are washed out the the most rapidly, and
3. That Si and Mg follow somewhat more slowly;
4. That we have a case of normal, continuous, subaerial leaching out.

placed side by side, it is difficult to make out just how this weathering goes on and how far it has gone and can go.

To round out the analyses of <u>volcanic ash</u> of Java already referred to in Part I of this book, a few additional ones have been found in the literature, namely one of Raoen ash[13] and four samples of Kloet ash.[14] These have been included in Table 115, page 560; as have also a couple of analyses of tuffs which had been developed from somewhat older ash. The one is a tuff from the Goenoeng Bangak, one of the small volcanoes belonging to the Lawoe group, also recorded by Verbeek and Fennema,[15] and determined as "a very

13. **A. H. Brouwer, De Raoeng en zijn jongste eruptie, Nat. Ts. Ned.-Indië, 73, (1913), p. 95. See also: A. J. Ultée, Meded Besoekisch Proefstat., No. 7 (1913), pp. 11-15.**

14. **Ch. E. Stehn, Keloet., 4th Pacif. Sc. Congr. Bull., 1, (1929), p. 22.**

15. **Verbeek and Fennema, Geol. Beschr. Java en Mad., I (1896), p. 247.**

much weathered, light gray rock," a hornblende andesite. The tuff (lying underneath black earth) is not gray, but almost white. At my request W. van Tongeren has gladly made the analysis of that sample which is recorded here. The other analysis, i.e. of the Bantam tuff which I carried out in 1913 is only partial,[16] but in spite of its incompleteness, shows how necessary it is to be able to have available more analyses of tuff which have contributed extensively to soil formation.

The following particulars may be noted about these data: The Raoen ash appears to be extremely rich in iron and at the same time poor in alkalies and Al. It consists almost exclusively of a volcanic glass which is very dark in color, in fact almost black because of the high Fe content. If this magma had had the time to crystallize slowly, the minerals magnetite, olivine and augite, now already visible under the microscope might possibly have far outweighed the plagioclase. Though it was not observed by Brouwer[17] presumably hypersthene would also be expected to be present. Thus in each case the ash must certainly be called basic. That in the analysis Ti and particularly P were not separately determined is indeed a very unfortunate omission.

Of the four samples of ash from the Kloet the two first mentioned were collected close to the crater, the second two at a great distance. While the influence of distance upon the composition is but small, yet it is still noticeable. The ash from close by has more Fe, Mg, and Ca, thus presumably somewhat more heavy, dark minerals. The ash samples from farther away contain more Si and alkalies, thus presumably somewhat more glass.

The tuff from the Goenoeng Bangak stikes one because of an especially low content of Mg and Fe. The dark colored bisilicates can thus be present only in small amounts and the glass is practically colorless. The tuff thus appears as an acid tuff. However it is not acid, for the SiO_2 content is but 56.49% and even calculated on the water free basis it amounts to only 60½%. This justifies at most the designation "intermediate." Since the iron, both FeO and Fe_2O_3, is present almost entirely as the minerals magnetite, ilmenite, and pyrite; and there is some iron as brown iron ore. So it would be plausible that upon weathering through subaerial leaching this type of tuff would not give rise to a dark brown or dark red soil, but rather a pale brown or pale red soil. With alternating wet and dry weathering it would give black earth, yet close to it, from tuff with many bisilicates or much dark glass, a dark brown or dark red soil rich in colloidal iron oxide would develop.

At least in so far as it has been analyzed, the Bantam tuff differs from all the rest of the rocks of Java because of a notably high content of Na, together with especially little Ca. It could hardly be the case that this is the result of weathering, of leaching out. For it is impossible that only the Ca should be diminished in this way while the Na increased. Moreover the K content is relatively high. The analysis wants verification and a more detailed one is needed. But with respect to the Bantam tuff, which is certainly in part a marine tuff, it is necessary to have for comparison the analysis of other marine tuffs. In the literature[18] there are to be found almost no analyses of marine tuffs, and certainly none from the Netherlands Indies. Such analyses would, however, be of great importance in answering the question as to how the volcanic minerals and the volcanic glass from ash and mud flow (lahar) material have been altered in sea water. Petrographically considerable attention has been given to this question, for on the basis of microscopic observations we have the terms choritization, serpentinization, and formation of glauconite. But chemically all these alterations under the influence of sea water have as yet been but

16. See: Meded. Alg. Proefst. v/d Landb., 18, p. VIII-IX.
17. Brouwer, l. c., p. 94.
18. See for example: F. W. Clarke, Analyses of rocks and minerals, U. S. Geol. Surv. Bull. 419. Idem., The data of Geochemistry, U. S. Geol. Surv. Bull. 695. F. Behrend and G. Berg, Chemische Geologie (Stuttgart, 1927). The chapter, "Submarine Gesteinszersetzung," (pp. 389-392) shows how little research has been done in this field.

Table 115

Volcano	Localities	Name of the Rock	By	Nr.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O+	H_2O-	TiO_2	P_2O_5	S	Cl	Total	Remarks	Where published
Danau	Lebak Bolong	Bantam tuff	MOHR	--	60.16	19.09			n.b.	3.15	1.70	7.49	2.02	6.41		n.b.	0.003	n.b.	n.b.		partial analysis	Med. Alg. Pr. St. Lb. 18 p: IX en 11 (1925)
Perangrang	Maswatie	Basalt	"	—	52.89	18.93	4.06	4.80	0.43	3.72	8.56	3.98	0.94	0.58	0.84	0.96	0.22	0.04	sp	101.05	incl. 0.10 CO_2	Bull. Dépt. Agr. Ind. Néerl. XXVIII (1907)
Tkb. Prahoe	SW—1950 m elevation	Basalt lava	REIBER	2476	57.41	17.27	4.08	5.42	0.18	2.12	5.55	3.02	3.24	0.53	0.32	0.84	0.29	sp	sp	100.27		Exc. Guide 4th Pac. Sc. Congr. (1929) (STEHN) (NEUMANN)
"	" —1870 m "	" "	"	2477	56.40	17.12	3.82	4.93	0.21	2.39	7.56	2.62	2.95	0.61	0.36	1.00	0.24	sp	sp	100.21		
"	" —1840 m "	" "	"	2478	56.25	17.89	3.81	4.78	0.18	2.32	6.95	3.09	2.78	0.44	0.41	0.94	0.27	sp	sp	100.11		
"	NE—1775 m "	" "	"	2475	54.12	19.02	4.80	3.16	0.18	2.68	8.16	2.82	2.94	0.49	0.28	1.10	0.28	—	—	100.03		
"	N—old crater	" " bomb	"	2431	58.03	18.43	4.29	4.82	0.10	1.83	5.40	3.13	2.41	0.47	0.30	0.80	0.13	sp	sp	100.14		
"	E—1800 m elevation	" "	"	2474	57.90	16.55	3.68	5.75	0.18	2.05	5.51	3.18	3.22	0.72	0.44	0.90	0.26	sp	0,02	100.36		
Goentoer	above Tjipanas	" " flow	"	2447	52.00	18.89	3.85	6.32	0.07	4.28	9.86	3.04	0.88	0.12		0.88	sp	—	0.06	100.25		
Galoenggoeng	W—side	Labrador basalt	DJOKOJOEWONO	4150	50.44	19.74	3.43	5.93	0.15	5.38	10.76	2.95	0.32	0.33	0.15	0.91	sp	n.b.	n.b.	100.49		Brief: Hoofd v/d D. v/d Mijnb. 7/11/'36
"	E—side	Augite hypersthene andesite	"	4148	55.71	18.70	2.58	5.19	0.15	3.62	8.39	3.91	0.67	0.58	0.12	0.77	0.10	n.b.	n.b.	100.49		
"	Eruption of 1894	Pyroxene andesite	"	1522	54.57	18.96	2.54	5.39	0.16	3.97	8.95	3.76	0.52	0.30	0.18	0.77	0.19	n.b.	n.b.	100.26		
"	Lava-dome 1918	Augite hypersthene andesite	"	260	56.23	18.60	5.66	2.48	0.18	3.51	8.14	3.87	0.65	0.17	0.05	0.77	sp	n.b.	n.b.	100.31		
"	" " S 1918	" " "	"	415	56.12	18.84	3.05	4.67	0.14	3.53	8.30	3.86	0.70	0.23	0.07	0.77	0.17	n.b.	n.b.	100.45		
Papandajan	Gg. Masigit	Pyroxene andesite	REIBER	2105	56.00	20.31	3.85	3.73	0.12	2.78	7.81	2.84	1.46	0.34	0.22	0.46	0.22		—	100.14		Exc. Guide 4th Pac. Sc. Congr. (1929) (NEUMANN v. P.)
Tjerimai	Southern edge of crater	Augite hypersthene andesite containing olivine	DJOKOJOEWONO	4237	53.91	17.36	2.63	5.60	0.15	5.47	9.06	3.12	0.98	0.78	0.32	0.83	0.19	n.b.	n.b.	100.40		Brief: Hoofd v/d D. v/d Mijnb. 7/11/'36
"	South below the crater wall	" " " " "	"	4233	54.43	18.56	2.44	5.48	0.15	4.36	8.73	3.27	1.15	0.84	0.07	0.83	0.19	n.b.	n.b.	100.50		
"	Geger Halang	" " " " "	"	4228	55.40	16.90	2.17	5.56	0.17	6.31	8.28	3.30	1.21	0.17	0.04	0.77	0.18	n.b.	n.b.	100.46		
	Goeha Waled			4229	58.33	17.55	2.34	4.70	0.15	3.38	7.00	3.57	1.70	0.31	0.08	0.80	0.22	n.b.	n.b.	100.13		
Slamat	—	Olivine basalt	REIBER	49	49.52	19.14	3.32	6.65	0.15	4.38	8.70	3.55	1.48	0.42	0.24	2.47	0.38		sp	100.40		Jb. Mijnw. N.O.-Indië 59 (1930), p. 258–262
"		" "	"	50	49.56	18.46	4.54	6.16	0.10	4.13	8.34	3.85	1.46	0.47	1.02	1.97	0.30	—	sp	100.36		
"		" "	"	51	49.70	17.36	5.28	5.53	0.12	5.04	9.14	3.18	1.44	0.77	0.24	1.97	0.56	—	sp	100.33		
"			"	52	50.03	18.11	3.48	6.06	0.19	5.85	9.30	3.02	1.10	0.53	0.20	1.65	0.68	—	sp	100.20		
"		Basalt	"	54	51.66	16.08	6.74	4.85	0.15	4.98	7.71	3.20	1.34	0.53	0.26	2.47	0.38		—	100.35	Here are included only those analyses of Slamat samples which have not been included in page 32	
"	—		"	55	52.28	19.39	1.24	6.58	0.11	5.02	9.12	3.41	0.98	0.24	0.08	1.55	0.30	—	sp	100.30		
"	—	Hypersthene andesite	"	58	54.23	18.10	2.88	5.03	0.15	3.85	7.72	3.66	1.79	0.47	0.55	1.52	0.38	—	sp	100.33		
"	—	" "	"	59	54.50	18.52	2.85	4.81	0.12	3.51	6.96	3.69	1.82	1.13	0.80	1.40	0.18		sp	100.29		
"	—	"	"	60	54.62	18.16	3.36	4.96	0.11	3.52	6.88	2.88	1.93	1.59	0.76	1.40	0.20	—	sp	100.37		
"	—	"	"	62	55.54	17.70	2.76	4.74	0.13	3.50	7.60	3.66	1.76	0.44	0.28	1.40	0.28	—	sp	100.19		
"	—	"	"	63	58.08	16.94	4.86	2.58	0.12	2.29	6.93	3.75	1.52	0.92	1.32	1.09	0.29		sp	100.39		
Dieng-Mountains	Gg. Peterangan	Augite hypersthene andesite with hornblende	DJOKOJOEWONO	4087	57.50	17.49	3.35	3.88	0.14	2.73	4.49	2.92	3.01	2.33	1.43	0.83	0.17	n.b.	n.b.	100.27	Lava flow, Eastern slope	Brief: Hoofd v/d D. v/d Mijnb. 7/11/'36
"	G. Pangonan	Augite hypersthene andesite	"	4100	55.64	17.91	3.19	5.13	0.14	3.20	7.16	3.65	2.07	0.62	0.45	0.93	0.15	n.b.	n.b.	100.24	" " South-Southeast wall of Merdodo	" " " " " " 7/11/'36. Ook: Jb. Mijnw. 1934/35, p. 82—83
"	Gg. Kendil Summit	" " "	"	4092	60.48	16.96	3.14	2.92	0.07	2.38	5.60	3.65	2.89	1.21	0.20	0.63	0.16	n.b.	n.b.	100.29	Containing biotite	
"	Naald: Pakoewodjo		"	4093	62.93	14.37	3.97	2.78	0.09	2.31	4.38	3.16	3.29	1.33	0.51	0.69	0.05	n.b.	n.b.	99.86	" "	
"	G. Srodjo		"	4104	55.76	17.85	4.75	3.60	0.15	3.27	5.93	3.23	2.52	1.59	0.73	0.89	0.17	n.b.	n.b.	100.44	Lava flow. East wall	" " " " " " 7/11/'36
"	Pagerkandang	Augite andesite with hypersthene	"	4090	53.08	18.26	6.81	2.64	0.08	3.27	7.17	3.11	1.86	1.39	1.82	0.95	0.02	n.b.	n.b.	100.46	" " West wall	" " " " " " 7/11/'36. Ook: Jb. Mijnw. 1934/35, p. 82—83
"	Telaga Mendjer	Basalt	"	2629	51.19	20.02	3.69	5.24	0.15	3.45	9.75	3.38	1.42	0.64	0.30	1.05	0.17	n.b.	n.b.	100.45		
Merapi, Cent. Java	Lava: 13/12/'30	Vitrified augite hypersthene andesite, containing hornblende	REIBER	89	55.60	16.91	6.39	2.87	0.18	3.04	8.02	3.63	2.14	0.05	n.b.	0.98	0.38	sp	—	100.19		Jb. Mijnb. N.O.I. 59 (1930), p. 261–262
"	Oostdom (3190)	" " " " " "	DEN HAAN	42	54.81	19.26	4.85	2.94	0.21	2.53	8.48	3.70	1.95	0.28	0.05	0.78	0.32		n.b.	100.16		" " " 60 (1931), p. 189.—Vulk. Med. 12, p. 76
"	Westdom (3191)	" " " " " "	"	43	54.81	18.90	5.56	2.49	0.17	2.70	8.60	3.58	2.15	0.13	0.01	0.84	0.34	n.b.	n.b.	100.28		" " " 60 (1931), p. 190.—Vulk. Med. 12, p. 76
"	Lava 1930 (3189)	" " " " " "	"	12	55.55	18.92	4.63	2.84	0.20	2.41	8.43	3.62	2.13	0.15	0.06	0.80	0.31	n.b.	n.b.	100.05		" " " 1932/'33, p. 88.—Vulk. Med. 12, p. 76
"	Lava 1931 (3193)	" " " " " "	"	7	54.95	18.98	5.40	2.23	0.17	2.49	8.60	3.62	2.13	0.21	0.11	0.83	0.38	—	n.b.	100.10		
"	G. Plawangan 1935	Labradoritic bytown basalt	DJOKOJOEWONO	8	52.59	19.34	4.43	4.39	0.23	3.24	9.60	3.79	1.68	0.23	0.06	0.87	0.03	—	n.b.	100.48		" " " 1934/35, p. 82
"	Lava 1934, gully between lava's 1930 and 1931	Augite hypersthene andesite	"	9	54.85	19.40	5.43	2.40	0.19	2.53	8.56	3.89	1.88	0.09	0.03	0.77	0.12	—	n.b.	100.14		
"	Trisingapoe, old lava	Augitic andesite-vitrified, containing olivine	"	10	53.14	19.57	5.28	2.83	0.07	2.83	9.08	3.54	2.00	0.51	0.16	0.83	0.27	sp	n.b.	100.19	incl. 0.08 CO_2	Partic. brief
Lawoe-Mountains	G. Bangak	Pale tuff	VAN TONGEREN	52	56.49	17.70	5.08	1.61	0.06	1.21	5.16	3.44	1.54	4.20	2.45	0.67	0.20	—	0.02	100.09	incl. (0.05 BaO, 0.01[5] Cr_2O_3	Exc. Guide 4th Pac. Sc. Congr. 1929, p. 7 (STEHN)
Kloet	Gadja Moengkoer	Basalt	REIBER	1012	55.39	18.05	4.98	3.34	0.21	3.48	9.28	2.82	0.84	0.76	0.41	0.28	0.08	SO_3:0.36	sp	100.28	trace SrO trace CO_2)	Brief: Hoofd v/d Dienst v/d Mijnb. 7/11/'36
"	G. Soembing	Basalt	"	2609	49.70	15.42	8.08	4.72	0.15	4.56	10.65	3.12	1.62	0.39	0.23	1.40	n.b.	n.b.	sp	100.45		Exc. Guide 4th Pac. Sc. Congr. 1929 (STEHN)
"	Lahar Badak near crater, 1919	Pale and dark ash	MONTGOMERY	1385	52.60	17.21	3.94	5.86	0.10	4.44	10.20	3.14	1.09	0.40	0.11	0.86	0.20	SO_3:0.16	sp	100.31		
"	idem	Ash	REIBER	1398	53.57	18.42	3.72	5.52	0.10	3.80	9.10	3.10	0.87	0.44	0.13	1.08	0.28	0.26	sp	100.39		
"	Soember Asin 1919	"	"	1391	57.04	17.79	4.25	4.08	0.09	2.64	7.82	3.63	1.06	0.46	0.14	0.86	0.19	0.31	sp	100.36		
"	Kediri, 1919	Basalt	MONTGOMERY	1397	58.00	17.21	3.14	4.01	0.10	2.84	8.52	3.12	1.30	0.61	0.18	0.99	0.18	0.21	sp	100.41		
Penanggoenan	S. 1300 m elevation	Acid basalt	KOOMANS	96	52.43	18.05	5.32	3.63	0.16	4.91	8.68	2.62	1.67	0.95	0.61	0.70	0.25	n.b.	n.b.	99.98		
"	SW—700 m elevation	Andesite	"	90	56.52	17.87	3.69	1.91	0.17	4.18	6.61	3.72	2.25	1.90	0.71	0.49	0.22	n.b.	n.b.	100.24		Leid. Geol. Meded. VII (1935), p. 283
"	E—1230 m elevation	Olivine basalt	"	99	56.78	17.47	3.27	1.44	0.13	4.79	5.66	3.85	2.29	2.30	1.27	0.58	0.20	n.b.	n.b.	100.03		
Tengger-Mountains	Kali Besi	Hypersthene andesite	WILLEMS	44	50.99	16.91	4.24	7.84	0.17	4.59	8.78	2.36	1.90	0.72	0.18	1.36	0.28	n.b.	n.b.	100.34	incl. 0.02 SrO	Jb. Mijnw. N.O.I. 60 (1931), p. 190.—See also p. 31 of this translation
" Smeroe	Djonggring Seloko	Olivine basalt	DJOKOJOEWONO	13	57.51	18.81	2.25	5.44	0.19	2.56	7.15	4.13	1.16	0.22	0.05	0.77	0.06	n.b.	n.b.	100.30		" " " 1934/35, p. 82
Lamongan	G. Anjer 1898		"	12	47.64	19.91	5.87	5.62	0.20	5.11	11.38	2.88	0.57	0.23	0.05	1.00	sp		n.b.	100.46		
Raoen	Wall of the Caldera	Basalt	KOOMANS	21	52.92	19.46	2.04	7.40	0.24	3.41	9.42	1.83	1.50	0.22	0.06	1.22	0.21	n.b.	n.b.	99.93		Leid. Geol. Meded. VII (1935), p. 333
"	" " "	"	"	26	54.99	17.21	3.57	4.26	0.25	3.49	9.58	2.18	1.87	1.01	0.37	1.15	0.34	n.b.	n.b.	100.27		
"	" " "	Augite hypersthene andesite	"	4	58.91	19.31	4.59	3.24	0.21	2.42	5.31	2.43	1.87	0.57	0.20	0.89	0.15	n.b.	n.b.	100.10		
"	" " "	" " "	"	5	58.23	18.27	3.70	3.12	0.14	2.18	8.58	2.45	1.76	0.37	0.23	0.86	0.24	n.b.	n.b.	100.13		
"	Gang in Wall of the Caldera	Basa	"	59	56.83	17.90	2.73	4.08	0.22	2.70	9.06	2.52	1.60	0.90	0.42	0.78	0.19	n.b.	n.b.	99.93		
"	Lava, centr. cone	"	"	46	52.93	19.25	3.06	5.01	0.28	3.78	9.79	2.23	1.79	0.39	0.02	1.02	0.25	n.b.	n.b.	99.80		
"	Bombs 1927	"	"	30	52.83	17.89	3.98	5.05	0.26	3.80	8.53	3.74	2.01	0.39	0.03	1.07	0.20	n.b.	n.b.	99.78		
"	Bombs 1927	Porous basaltic slag	"	34	52.40	18.71	2.93	5.09	0.23	3.71	10.29	2.95	2.30	0.33	0.01	1.00	0.18	n.b.	n.b.	100.13		
"	Ash 1913	Basaltic ash	HOLLEMAN	I	53.97	14.95	10.62	7.72	n.b.	2.69	8.12	1.17	0.65	0.62		n.b.	n.b.	n.b.	n.b.	100.51	incomplete analyses	BROUWER—Nat. Tschr. N.-Indië 73, p. 95 (1914)
"	" 1864	" "	BLEEKRODE	11	51.45	22.70	14.20		n.b.	3.84	7.64	1.07	0.69	1.31		n.b.	n.b.	n.b.	n.b.	99.90	" "	BROUWER—Nat. Tschr. N.-Indie 73, p. 95 (1914), en—idem 28, p. 154 (1865)
Merapi, Idjen	SE wall, K IV	Plagioclase andesite	DJOKOJOEWONO	4044	54.06	19.62	4.58	3.61	0.14	2.85	7.91	3.78	1.37	0.91	0.59	0.83	0.06	n.b.		100.31		Brief: Hoofd v/d D. v/d Mijnb. 7/11/'36
"	inner crater	Feldspathic basalt	BALTZER	440	58.35	15.67	12.90		n.b.	1.61	5.68	4.05	3.12	n.b.	n.b.	n.b.	n.b.	n.b.	n.b.	101.38	" "	STOEHR—Abh. Senck. Nat. f. Ges. IX, p. 1—120 (1873)
"	Oengoep[2]	Augitic andesite	NÖLDECKE	411	60.22	19.12	4.63		n.b.	sp(?)	5.89	7.60	2.40	n.b.	n.b.	n.b.	n.b.	n.b.	n.b.	99.86	" "	
"	Batoedodol, lava	Basalt	WISLICENUS	460	54.04	13.90	15.41		n.b.	3.84	9.82	1.07	0.69	1.31		n.b.	n.b.	n.b.	n.b.	100.08	" "	
	Gradjagan	Old andesites	FUCHS	490	62.74	17.02	3.13	2.10	n.b.	0.42	7.59	3.33	1.73	2.12		n.b.	n.b.	SO_3:0.58	—	100.76	" "	
	"	" "	WISLICENUS	5010	61.20	18.52	2.69			0.95	6.34	5.48	2.96	2.15		n.b.	n.b.	—	n.b.	99.93	" "	
	K. Toelis	Miocene contact shales	DJOKOJOEWONO	805	59.48	16.71	1.19	5.50	0.22	2.90	2.78	6.11	0.19	3.49	0.53	0.64	sp	n.b.	n.b.	99.74		VAN BEMMELEN—De Ing. in N.I. 1937, IV, p. 134
	Lab. Kerambi	Basalt	DJOKOJOEWONO	1/8	47.69	12.14	6.81	1.85	0.15	7.42	13.50	2.17	5.45	0.89	0.32	0.86	0.86	n.b.	n.b.	100.11		Jb. Mijnw. N.O.I. 1933/34, p. 88.—Mijning. 14 (1933), p. 198
	Zijtak K. Doerasman	Leucitic basalt	DEN HAAN	4/7	47.61	12.67	5.46	2.70	0.12	6.96	11.78	0.73	6.35	2.16	1.81	0.86	1.04	n.b.	n.b.	100.25	Strongly divergent from the rest, as regards Al_2O_3, MgO, CaO, K_2O, Na_2O, H_2O, etc.	" " " 1933/34, p. 88
	K. Selogono	" "	"	3/-	50.84	20.63	4.07	1.48	0.16	1.24	5.17	1.85	6.62	5.19	2.37	0.54	0.29	n.b.	n.b.	100.45		
	K. G. Tamboeboekir	" "	"	2/-	47.16	18.38	5.31	3.67	0.28	2.70	9.47	4.24	1.32	5.08	1.83	0.81	0.66	n.b.	n.b.	100.91		
	?	" "	?	-/6	47.41	12.23	4.99	3.10	0.16	7.44	12.27	2.13	5.92	1.60	1.22	0.77	0.80	n.b.	n.b.	100.04		De Mijningen. 14 (1933), p. 198
	?	" "	?	-/5	46.97	14.93	3.60	2.82	0.13	6.98	13.07	1.32	5.98	1.70	0.99	0.90	0.83	n.b.	n.b.	100.22		
	?	" "	?	/-4	46.12	12.57	5.75	3.33	0.15	8.53	12.36	2.16	5.83	1.13	0.71	0.66	0.99	n.b.	n.b.	100.29		

n. b. = not determined
sp. = trace

very inadequately investigated. Since on Java many marine tuffs as well as land tuffs from the same volcanoes are the parent material of soils, there is ample justification for giving at least a little attention to the geochemical processes involved. A priori a difference is indeed to be expected between the soil types developed on these different tuffs. As to how great those differences will really prove to be and in which directions they will lie, there is at the present time not a bit of experimental data. The fact that the beginning of weathering took place under the sea, not only in a salt solution, but in one with a pH of about 8.4, should, on the basis of what has already been discussed on pages 526-528, certainly have had an important effect upon the course of the weathering, in that from the beginning there is a tendency to form clay minerals with a high absorptive power. It is obvious that although it might be very difficult to detect any difference with the naked eye, such a difference as here indicated should make a big difference in the final result. Moreover, it is obvious that marine tuffs should and do possess the constituents Fe, Mg, Ca, Na, and K in other mutual relationships than do the corresponding terrestrial tuffs; consequently this must lead to practical differences. On account of this we must give more attention to the differences between marine and land tuffs than has been the case heretofore.[19]

A number of sedimentary rocks are associated with the tuffs on Java. They are combined with the tuffs in such a way that, in a certain sense, they form a continuous series. This is in agreement with what was described and illustrated by schematic figures 3 and 4, pages 11, 12.

For the greater part the sedimentary rocks of Java are of Middle Tertiary age or younger. Thus from a time, geologically speaking, during which somewhere or other there was continuous volcanic activity on Java. This activity scattered ash and coarser ejecta over the land, and also in the sea surrounding the volcanoes. For this reason practically all the sediments which have now been changed to solid rocks possess more or less volcanic material. In some this is so predominant that without any question they can be called tuffs, although such rocks also contain considerable calcium in the form of Foraminifera. But there are also rocks, particularly in the north of East-Central Java, which do not have any calcium combined with the volcanic constituents but instead contain sand from older rocks, which possibly were granites and perhaps also schists.

In the table of analyses there is one analysis of a Miocene shale slightly altered by contact metamorphism. As to the urgent need of more analyses of limestones, marls, claystones, sandstones, marine tuffs, etc., we need not here enlarge upon the question. However in closing we may add that the justly great interest in the so-called "trace elements," or minor elements, has so greatly increased in recent years that in the future we will scarcely be able to leave them out of our investigations.

The Climate of Java and Madoera

With reference to the climate of Java and Madoera in general, there is but little to be added to what has already been stated in pages 41-70.

In comparison with Borneo and Sumatra, the area of Java is much smaller, nevertheless Java shows greater climatic differences than do the two other islands. Even within the limits of a single district we find so much variation that of the 6 colors on the map (Fig. 6), for example, at least three fall within each district, and in the two most easterly districts, there are all six colors in each district.

It is especially because of the East and West monsoons which on Java are both equally strongly marked that there are such great variations in the climate. But at the same time the orographic nature of the island, with its numerous volcanoes in almost every district, in part standing isolated in plains at about sea level, which rise up to elevations of 2,000 and to even higher than 3,000 m., which have such great

19. In this connection compare what is said in Blanck's "Handbuch der Bodenlehre" under the heading "Halmyrolyse"; for example, in II, p. 159.

differences in climate on their windward and lee sides. On all the maps relating to the rainfall, including the map in this book mentioned above, these differences can be seen at a glance.

It is obvious that here only those characteristics of the climate of particular importance for the soil demand attention and, seeing that nothing more is to be added to the general data of Part I relating to the temperature, we here need to consider only questions of moisture.

A couple of attempts in this direction follow: With the eye upon the questions of runoff, for a number of places the annual and monthly figures[20] of the rainfall have been divided by the number of rainy days. In this way the following maxima and minima for a single rainy day (see Table 116 below) have been obtained.

If these data are graphed with the rainy days as the abcissa and the rainfall as the ordinate, then the points by no means lie along a single line, but enclose a large area in which all other points indicating observations may be plotted. In that field can be drawn lines out from the zero point for the average rainfall per day, and the whole field mentioned above remains within the lines 9 and 40. Particular regions or districts will be noted as smaller groups of points within the larger. Such for example, are the high plains surrounded by higher mountains, the points of which all lie below the line 15. These localities are the Idjen plateau, the plateau of Bandoeng, and the plateau of Pengalengan. Further, all places along the coast which are exposed to the direct force of the West Monsoon lie above the line of 30 mm. per day; for example, Laboean and Tjiletoe and also North Djapara. The mountain slopes facing outward toward the sea between 200 and 1,000 m. elevation all have a heavy rainfall, but their daily precipitation generally lies between 20 and 35 mm.

The conclusion is thus obvious,--the high plains, in themselves already flatter than the slopes, have less runoff than the outer slopes, while the inner slopes occupy an intermediate position. Very roughly we thus again come to the conclusion that the best lands for the cultivated crops must be found in the high plains; next best should be the inner slopes of the mountains, and least desirable the outer, exposed slopes.

Regions where the average rainfall per rainy day does not rise above 10, or at most not above 15 mm., may yet now and then have very heavy showers, but as a whole not so heavy that heavy spates rush down the rivers. For example, see Table 117, page 563.

Now if we compare with those figures how many times the average daily maxima of more than 400 mm. occurs on the outer slopes: then it is clear why the sudden, heavy spates or floods occur especially in the coastal regions (see Table 118, page 563). Seeing that for the places given in the last mentioned table the

Table 116

No. and District		Place	Number of years of observations	Average annual rainfall	Average number of rainy days per year	Average rainfall per rainy day
				mm.		mm.
Bjms.	25	Tendjo	13	**6897**	219.7	31.4
Pr.	72	Panggeranggo	17	3296	**284.2**	11.6
Btm.	6	Laboean	12	4102	103.6	**39.6**
Bski.	130	Asembagoes	34	**909**	73.3	12.4
Bski.	42a	Tdg. Patjinan (Pandji)	9	1119	**45.4**	24.7
Pr.	63	Bandoeng (Blind. Inst.)	12	1778	195.9	**9.1**

20. These figures have been taken from: Verh. 24 v/h Kon. Magn. Meteor. Obs. Batavia (1931).

Table 117

District and number	Place	Number of years of observations	Average rainfall per day	Average daily maximum during the years	Absolute maximum for a day
			mm.	mm.	mm.
Pr. 68	Tijipanas	16	14.4	82	95
Pr. 146	Tjiboeroei	23	11.9	68	104
Pr. 151	Batoedjadjar	16	11.6	69	86
Pr. 152	Tjimahi	31	10.7	69	104
Pr. 180	Malabar	31	12.6	73	93

Table 118

District and number	Place	Number of years of observations	Average rainfall per day	Average daily maximum during the years	Absolute maximum for a day
			mm.	mm.	mm.
Btm. 4	Padarintjang	33	26.2	182	460
Btm. 6	Laboean	12	39.6	240!	360
Pr. 19	Tjiëmas (Bodj. Genteng)	17	31.1	201	400+
Pr. 116	Tjibintaro	14	25.4	225!	361
Pr. 239	Tjimangkak	26	27.3	197	421
Pr. 251	Tjikentreng	13	23.4	229!	425
Ch. 50	Sadareke	39	26.1	200	335
Pek. 120	Batang	24	30.2	221!	379
Pek. 124	Doro	33	22.6	163	495
Pek. 125	Lebakbarang	33	28.7	183	406
Pek. 129	Tombo (irr.)	15	29.8	207	450
Pek. 134	Soebah	24	18.3	146	405
Pek. 139	Pagilaran	33	25.8	173	431
Bms. 44	Adipala	14	20.3	199	650
Smg. 3	Besokor	31	18.5	157	511!
Smg. 152	Petjangaän	24	20.9	158	420
Smg. 159	Baé (Tjendana)	36	21.3	150	600!
Ked. 142	Kadamangan	20	23.3	173	564!
Pas. 130	Soember Tjoeleng	14	20.5	206	420!
Pas. 167	Soember Rowo	32	26.8	215	400+
Bsk. 7	Boedoean	24	17.6	141	400+

average rainfall per day is hardly ever less than 20 mm., in all cases where that figure is 20 or higher one should be inclined to pay special attention to erosion and floods. But more than that one cannot say, because other factors, such as the nature of the rainfall (duration of the heavy showers in hours and minutes), as well as the slope of the land and the condition of its vegetative cover, the nature of the surface of the soil and its perviousness, etc., have such a marked effect upon the rate of the runoff.

In view of all this--just as a tax

assessor who is endeavoring to arrive at a reasonable tax cannot escape handling each assessment separately--similarly there is no other way to get definite results but by observing the rainfall shower by shower, and to study where that rain water goes. One cannot arrive at any definite result with "average figures" alone.

Of much significance in this connection are the transpiration through growing plants and the forms of vegetation. In this field an important contribution has been made by Coster.[21] Since he has dealt fully with this question we need not here enlarge upon it further.

Regarding the duration of sunshine, relative humidity of the air, wind, and the influence of these climatic factors upon the temperature and the moisture content of the soil at different depths, the available data are still too inadequate to here do more than to add a little something for Java in particular.

* * * * *

An endeavor was made to obtain a provisional rough insight into the water relationships. This was done on the basis of the rainfall and the discharge of the rivers. There are several rivers, of which the discharges have been measured over a number of years. But these are relatively small mountain rivers which are used for the generation of power. Among these only a single one, the Tjitaroem, is of a considerably larger size. There is the further unfortunate fact that while the plains below swarm with stations for measuring rainfall, up above in the mountains there are but very few stations. The estimations of the rainfall, for one cannot consider them more exact than that, in the drainage basins above the gaging stations for measuring river discharge are consequently far from accurate.

Of the very large rivers, such as the Solo, the Brantas, the Tjitaroem, and the Tjimanoek, there is not to be found in the literature a single statement regarding the amounts of water they discharge into the sea. Moreover, in their central and lower courses all these rivers are tapped again and again for irrigation, which by no means simplifies the questions of the water relationships. Yet it appears that with some additional discharge figures from the lowland, which are still to be obtained, let us see what now follows for the mountain rivers.

The Department of Commerce, Buildings and Roads issues annually[22] a report of the data on water observations. These include the height above the sea (H), the drainage basin area (S) in km.^{2}, the observed daily discharge in cubic meters per second (m.^{3}/sec.) and rainfall averages over a number of years. From the stated average monthly discharges a rough average discharge in m.^{3}/sec. can be calculated, and this multiplied by 3600 x 24 x 366 gives the annual discharge (A). The rainfall[23] from the area S gives the total quantity of rain water fallen (R); and there is expressed in %, what part A is of R. It may be accepted that in general R-A is the total evaporation, i.e., the loss from the soil plus the rain water evaporated directly from the vegetation, and transpiration through the vegetation. The data in Table 119, page 565, were treated in this way. The classification was made according to the relationship 100 A/R.

The notable thing about this Table 119 is that no matter how rough the basic data may have been as a point of departure, the following points are clearly evident:

1. From 2/3 to 1/3 of the rain, but neither more nor less, leaves the land via the river; obviously steep slopes increase the amount, while large plains diminish it.
2. Although the total annual rainfall varies between 2.5 and 5.5 m., the evaporation varies, taken by and large, between 1 and 2 m. These

21. Ch. Coster, De verdamping van verschillende vegetatievormen op Java., Tectona 30 (1937), pp. 1-112.
22. Statistiek v. waterwaarn. (Hydrometrie), Versl. en Meded. v/h Water-kadaster No. 18 (1936) and earlier years.
23. Since these differ considerably from year to year, the years 1929 and 1930 have been taken, these are the last for which the rainfall observations of the Royal Magnetic and Meteorological Observatory have been published.

Table 119

	Elevation	Drainage basin area	Rainfall per year	Average discharge $m.^3$/second	A in % of R	V = R-A	Particulars about the drainage basin
	m.	km.^{2}	mm.		%	mm.	
Tjianten II-Kratjak.	270	143	5340	15.85	65.4	1861	1. Forested mountainous land, with some cultivated land.
" "	270	143	5392	15.57	63.6	1963	2. Forested mountainous land, with some cultivated land.
Bogowonto	360	94	3893	7.34	63.2	1437	3. Paddies and a little light vegetation.
K. Baroe-Banjoewangi	308	136	2882	7.81	62.8	1072	4. Heavy forest, coffee and rubber, paddies.
Tjilaki.............	640	163	2561	8.24	62.2	968	5. Forested mountains and tea gardens.
K. Konto I	892	110	2132	3.62	48.7	1094	6. Forested mountains.
" I	892	110	1850	3.66	56.6	803	7. " "
" II	575	235	1937	8.36	57.8	817	8. Forested mountains and light vegetation and some paddies.
Tjitjati	251	485	3142	26.3	54.2	1439	9. Forested mountains and many paddies.
Tjisadane	373	129	4470	9.84	53.7	2070	10. Light vegetation on west slope of Mt. Gedeh; many paddies.
"	373	129	4430	9.25	51.0	2170	11. Light vegetation on west slope of Mt. Gedeh; many paddies.
K. Serajoe	1035	58	3605	3.53	53.2	1687	12. Little forest, little vegetation on mountainous land.
Tjitaroem	132	4150	2630	150.4	43.4	1483	13. Forested mountain land and the plain of Bandoeng.
"	132	4150	2638	150.1	43.2	1498	14. Forested mountain land and the plain of Bandoeng.
Tjidano	82	201	3340	9.70	45.5	1820	15. Danao swamp and forested slopes.
"	82	201	3283	8.54	40.8	1943	16. " " " " "
K. Toentang	459	282	2501	10.7	42.8	1430	17. Light vegetation and Pening swamp. Paddies.
Tjipelas	282	310	2825	11.8	42.4	1627	18. Forested mountain land and tea gardens. Many paddies.
Tjimanoek	585	751	2892	25.0	36.4	1840	19. Forested slopes, plain of Garoet, paddies, fish ponds.
Tjisangkoei	1040	104	2825	3.25	34.5	1847	20. Forested mountain lands, Cinchona plantation.

figures fall quite within the limits obtained by an entirely different method (Tables 31, 32 ff. pages 52, 54.)

With the scarcity of basic data it does not appear practicable to try to give the figures for evaporation, which would include the rain which evaporates from the soil, the water which the plants lose by transpiration, and the water which evaporates from the paddies.[24] However, if but first an adequate number of detailed studies are available, we need not doubt but that it will some day be possible.

24. Not to be forgotten is the water which sinks down so deeply into the earth that it passes outside of the drainage basin (at least beyond the stream gaging station), so that in the above calculation this water is included in the evaporation.

Ways in Which Weathering Takes Place and Resulting Soil Types on Java

If the general considerations worked out in Part I of this book and shown on the colored map, Fig. 6, are correct, then definite weathering forms and soil types occurring in the tracts colored yellowish-green, orange, and red on this map must be lacking in the regions colored blue and vice versa.

Thus, for example, we find the typical black-earth clay, with or without a horizon of lime concretions, in Soerakarta, Semarang, Rembang, Madioen, Kediri, Soerabaja and Pasoeroean. But west of the line through Semarang and Jogja-karta this black earth occurs almost only along the north coast, in the green or orange areas of the map, in localities such as Kendal, Tegal, and Indramajoe where the parent material is particularly suited for the formation of this soil type. Nor are lime concretions found in other than the black earths in the soils of the blue regions, nor has gypsum crystallized out in these soils. These soils are thus different from those which have been weathered from limestone and marls, lying between Semarang and Soerabaja, thus in green and orange areas, and in which gypsum is often found.

On the contrary we do find marls weathered to red and yellowish flecked lixivium (Buitenzorg, Tasikmalaja, Bandjarnegara), but not on the marls in the green and orange areas. The few places where peat has formed[25] on Java are also all limited to the blue areas.

The colored map, Fig. 6, not only indicates whether we may expect a certain soil type in a certain locality or not. But also with reference to generally widely distributed soil types, from the map we can also roughly estimate the proportions of the different types. For example brown to red lixivium soils in the senile stage, which is the stage wherein weatherable minerals are no longer present, are much more intensively leached out if they are lying in the rain-rich, blue areas of the map, than if they fall within the rain-poor, orange areas.

Along with the more or less strong leaching of the soil is connected the greater or less depression of the pH. In general soils lying in the blue areas of the map will have lower pH values. Conversely the sugar soils of Java, occurring mainly in the green and orange areas of the map must thus also have on the average higher pH numbers. This was clearly shown by data presented by Arrhenius[26] in tables and maps. From these it appears that in the eastern tip of the island, where most of the sugar soils come within the orange and even red areas of the map, the pH lies between 6 and 9, averaging $7\frac{1}{2}$. In Djombang, Kediri and Madioen (orange and green) the reactions average 7.2; in the Principalities of Eastern and Central Java (predominantly green) 7.0; in Banjoemas (green, blue) they average 6.7. With a lower pH sugar cane cultivation does not generally succeed, for acid soils give too low a yield of sugar.

Tea is just the opposite; this crop prefers pH figures[27] between 4 and 6. Corresponding with this it will be noted that in general the tea soils all fall within the blue areas of the map. Cinchona (quinine) prefers a somewhat higher pH, between 4.5 and 6.5, with an optimum at about 5.6.[28] This crop also grows exclusively within the blue areas of the map.

Horticultural extension agent Terra told me that the distribution of most of the fruit trees is also closely correlated with the frequently referred to climatic map.[29] For example varieties of fruit trees which prefer regions within the blue areas, do badly or as a whole do not

25. See: E. Polak, Ueber Torf und Moor in Niederl. Indien., Verh. K. Ak. v. Wet., Afd. Natuurk. 2e Sectie. XXX (1933), No. 3.
26. O. Arrhenius, Een orienteerend onderzoek over den zuurgraad van de suikerrietgronden op Java, Meded. Proefst. Java Suiker Industrie (1927), No. 6, Arch. S. Ind. Ned.-Indië (1927), pp. 207-228.
27. Cf.: P. M. H. H. Prillwitz, Invl. v/d basentoest. v/d grond o/d ontwikk. v/d theeplant, Arch. theecult., VI, 2/3, pp. 1 and 2.
28. M. Kerbosch and P. Pzn. C. Spruit, Beoord. kinagronden, enz., Cinchona, VI (1929), p. 73.
29. This has been definitely stated in: G. J. A. Terra, Versl. 15e Bijeenk. der Ver. Proefst. Pers., (Oct., 1935), pp. 117-141.

succeed at all within the orange and green areas, and vice versa. In conclusion, I recall the communication of C. A. Backer, the botanist, in which he stated that a map of the climate such as the one here referred to had in numberless cases indicated the reasons for the distribution of the native plants growing in Java.

It should be mentioned here that this correlation between plant growth and climate is certainly sometimes direct, although in many cases it is still quite as certainly indirect in this sense, that the climate to a great extent has determined the character of the soil, and the soil determines the plant growth. With tea and cinchona pH determinations clearly illustrate the latter, and we may well accept that for a number of other plants similar conditions hold good. But the fact in this discussion which is to us of most importance is that there is the close correlation between climate and soil, so that from a map of the climate, as mentioned above, one who realizes the relationships can tell a great deal as to the characteristics of the soils.

In comparison with the other islands, Java has much more important differences in climate. In climate West Java is more like Sumatra, while East Java more closely resembles the Smaller Soenda Islands. Moreover Java has both mountain soils and lowlands. For these reasons alone, there must thus be quite a good many different ways in which weathering takes place, for example, from the one predominant parent material, andesite, plus tuffs, plus ash, there has arisen a rich diversity of soil types. If we were to differentiate the terrestrial tuffs from the marine tuffs, the gradations from tuff to marl, the series from tuff to limestone, etc., and then if in addition we split up the andesite into hornblende andesites, augite andesites, basalts, etc., then it is better that in these general considerations we do not attempt to do all of this for Java as a whole. Such details belong rather in the later consideration of the different regions of Java which will be discussed in succession from the west toward the east; and further details of certain of these regions will also be discussed from north to south.

With reference to soil research on Java in general, and regional soil research and soil mapping of particular localities, it may here be recorded that Jogjakarta and Soerakarta have been completely mapped by the Soil Science Institute at Buitenzorg on a scale of 1:100,000 but even yet (1938) this survey has not been published. This institute has subsequently undertaken the study of a couple of other areas in Java, but except for a portion of North Bantam, I could not obtain any information as to the results of those studies. In the literature there do exist various older soil surveys and maps of parts of Java; these will be considered in the discussion of the respective districts.

There are also a number of other sorts of maps which are of value in connection with the soil of Java and Madoera. Such are irrigation maps, forest maps, and maps relating to the distribution and the yield of the different crops. They all help one to make deductions relating to the soil, but give no direct primary observations with respect to the soil itself.

* * * * *

WEST JAVA

By West Java we mean that part of Java lying to the west of the north and south line connecting Cheribon, Koeningen, Bandjar, and Parigi. While this boundary does not include quite the same limits as the administrative district of the same name, it is more practical for the purposes of this book. Subsequently we will also subdivide the rest of Java independently from the administrative subdivisions, drawing lines to indicate distinct soil and climatic differences.

For these separate portions of Java it seems desirable to depart from the method of treatment of the subject previously used. Therefore we will not divide the regional discussions into separate sections dealing with the parent rocks, the climate, etc., as we have done previously for the other islands. Moreover from that point of view we have already considered Java and Madoera as a whole, under those topics in the three preceding general sections.

* * * * *

Let us begin by considering various points regarding that part of Bantam which lies west of a line running northeast and southwest through Pandeglang. If we draw a second line, running east and west from Rangkas, through Menes to Laboean, then to the north of this line there lie the mountains and south of it low plains or at most low hilly land. Most of those mountains belong to the Danau range, on the south and southeast sides of which a few younger volcanoes have grown up, of which the Karang and the Poelosari (see Fig. 198, page 569) are the most prominent. According to Verbeek[30] these are "beautiful cones, covered with vegetation right to the top." The surface soil is deeply weathered to a "red clay"; this would more correctly be termed brownish red to brown lixivium. The rock making up these mountains is on the basic side: pyroxene andesite and basalt, with a distinct olivine content. Lava flows are infrequent, conglomerates and breccias are not abundant. Finer lapilli and an ash appear to be the predominant parent materials from which the soils have been formed. As a result of a high content of colloidal iron hydroxide these materials have given rise to a soil with a loose structure excellent for the wild vegetation and cultivated crops. As a consequence of the heavy rainfall, especially on the southern and western slopes, the intensive leaching has reduced to a low level the content of plant food substances[31] in the soil which is already a quite senile reddish brown lixivium. Consequently in this region we do not find any of those crops which make heavy demands upon the soil, while at the higher elevations where tea or cinchona ought to grow very well both volcanoes are, as it happens, too much dissected and rough and steep. Upon the somewhat flatter lower slopes there are a few nice rubber plantations similar to those on Borneo and Sumatra. If the physical condition of the soil is good and rainfall is continuously abundant, Hevea requires but small quantities of plant nutrients from the soil.

Danau mountain which has just been mentioned is an extensive but low volcanic ruin. It is doubtful whether it ever had a high summit. The crater floor is at present a marshy plain,[32] draining off to the west over a hard[33] lava threshold through the small Tjipasangteneng river. It is likely that formerly this threshold was higher because of the masses of tuff and that then the crater plain was occupied by a permanent lake. At present during the height of the rainy season the stream referred to cannot drain off sufficiently rapidly all the water which flows in from the surrounding slopes, so that for a large part of the year the plain is submerged. In the following dry season, or more correctly the less rainy season, the lake shrinks to a very much smaller size and the rest remains as swamp (see Fig. 199, page 569). Meanwhile, flowing out with the river water coming from the north slope of the Karang and from the slopes to the west, a considerable quantity of silt comes onto the plain which, especially in the south, is being filled up to an important degree. Already a large part of the original swamp forest has been converted into fertile paddies. In the plain the soil was originally subaqueously weathered. Now in the south the paddy soils are more and more amphibious, yet the earlier character of the soil is still predominant. The plain lies about 100 m. above sea level, nor are the other conditions for peat formation very favorable. Besides, the not very senile tuff material being washed into the plain does not bring with it an especially low pH, and so is not conducive to peat formation. These are the reasons for Endert's statement that "the Danau is a swamp and not peat."[34] The soil is "a true mud," certainly "for the greater part consisting of wood fragments, but the mass

30. Verbeek and Fennema, l. c., pp. 864-867.
31. E. C. J. Mohr, Rubber Recueil, (Batavia, 1914), p. 170.
32. F. H. Endert, The natuurmonument Danau, Tectona 25 (1932), 963-986. This extensive monograph, which includes a map and beautiful photos, has supplied various facts which have been incorporated in this discussion.
33. J. A. Hardeman, Mem. Overg. Resid. Bantam, (April, 1906), p. 40.
34. Endert, l. c., p. 971.

Photo by Bley

Fig. 198. Bantam. View looking west from the Pasir Ajoenan Rubber Plantation. The volcanic cone G. Karang in the center and G. Poelosari at the left. Between the two and in the extreme distance is G. Asoupan. In the foreground second growth forest and rubber plantation on Bantam tuffs.

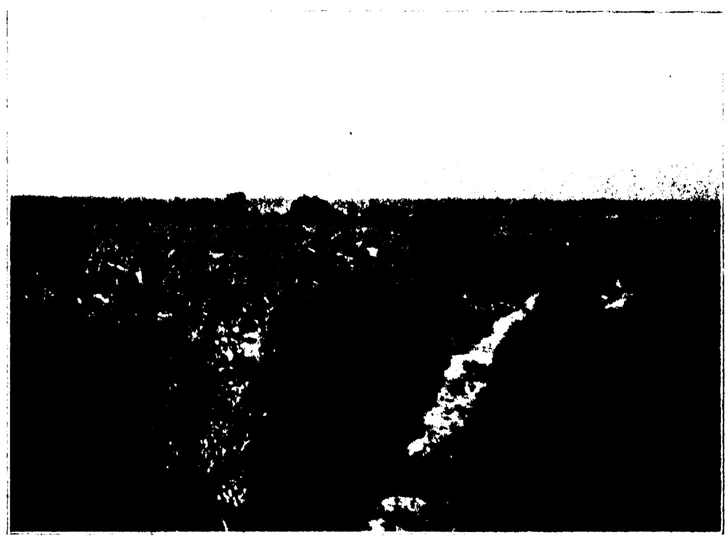

Photo by H. J. Lam

Fig. 199. The Danau plain, Bantam. In the distance is the forest, within which is the lake. In the far distance the remains of the crater wall.--The soil of the plain is pale, for the greater part subaqueously weathered.

Photo by Bley

Fig. 200. Irrigation canal near Pamarajan, Bantam. Slumping out of the canal banks excavated in white tuffs. The vegetation is not luxuriant on the only slightly fertile tuffs and the pale soil weathered from them.

will not burn and thus is not peat." This also agrees with what he says[35] somewhat further on regarding the occurrence of a fern, peculiar to the flood forests: "Its frequent occurrence in this region must apparently be ascribed to the water having a high content of mineral salts as a consequence of volcanic influences." Particularly in connection with what has already been discussed (pages, 72-74) an analysis of the water and the determination of its pH would be very much in order.

The Danau volcano gives the impression that it has not been built up so gradually and "respectably" as the Karang and the Poelosari, but rather as the result of a few very heavy eruptions, really explosions, during which enormous quantities of ejecta were thrown into the air. Yet not entirely in that way, for Verbeek in his conclusions regarding the Danau says[36] "This mighty volcano has thrown out two sorts of rocks. First, pumice stone and obsidian, apparently only as loose ejecta. Secondly, pyroxene andesite and basalt along with transition forms of these rocks....which, as layers of lava, alternate with the pumice stone tuffs. The 'white tuffs' of the Quaternary formation of Bantam and a part of Batavia are submarine products of this Danoe volcano" (see Fig. 200 above).

Two points already previously[37] mentioned by Verbeek may appropriately be referred to here. First, that in the time of the greatest activity of this volcano the sea stood about 100 m. higher than at present. That is, the point of eruption was below the level of the sea, as a result of which it is obvious that the conditions were different from those on land, where a steep volcano can be built up. Not only that under water the angle of repose can never be nearly so steep as on land but that the currents in the sea played a part, particularly if at the time

35. Endert, l. c., p. 973.

36. Verbeek and Fennema, l. c., p. 967.

37. Verbeek and Fennema, l. c., pp. 871-876.

of the eruptions they were setting strongly from west toward the east, as is the case at present during the west monsoon months. If so the ejecta would have been carried away before they had had time to sink to the sea bottom.[38]

Secondly, Verbeek considered it "not impossible that a small part of the Bantam tuff was ejected through independent submarine points of eruption."[39] Adequate evidence for this, however, is lacking. Only the astonishing quantity of tuff which for example, lies more than 200 m. thick at Serang and still many tens of meters thick at a distance of tens of kms. from the point of eruption, naturally raises the question: has all that material come from only one point of eruption? It is the same question which also arises repeatedly on Sumatra and it is not an easy one to answer. Later researches concerning Bantam, among others those by White and Scheibener,[40] have given us no new light on this question. However, on the grounds of the very close similarity of the Bantam tuffs with dacitic Pleistocene tuffs in the Lampongs, Sumatra, it does seem likely that the Danau products must have been spread out very extensively, not only toward the east over Java, but also toward the northwest over Sumatra.

Meanwhile it is of great importance in carrying out the purposes of this book to determine, as calculated below, the limits on the present day land surface of the area of the Bantam tuffs which are purely land tuffs; and those which are marine tuffs and which from the moment when they were erupted into the sea, were "pre-influenced" as it were by the sea water, previous to their becoming land and, as such, a parent material for weathering to soil. Regarding this, factual data are available in the form of detailed analyses of the tuffs themselves, as well as of the soil types which have developed from these tuffs, and the kinds of soil materials which make up the soil profiles.[41] At present about all we can say about this question is the following: Obviously the marine tuffs were not suddenly raised up from the bottom of the sea, but only gradually. Consequently the surface portions passed through the stages of first sea bottom, then coastal swamp, and finally dry land. Speaking geologically, the coastal swamp was rapidly covered with forest and although the sea water previously in contact with the material was well over pH 8, the dense tropical rain forest vegetation depressed the pH of the water. Ultimately the pH of the swamp water fell to such low values that here and there peat could form, especially in depressions parallel to the coast. When excavating for the foundations of the Tjioedjoeng project examples of this peat on, and especially between, the tuffs were repeatedly found; nor was this always a pleasant surprise. Where because of these conditions favorable for the formation of peat the pH was depressed to below $4\frac{1}{2}$, the iron oxides became movable, and in other places, either deeper or to one side, where the pH was still higher, these iron compounds were again precipitated as iron concretions, as hail ore, or bean ore, and often coalescing to solid masses of concretions. This is not an infrequent phenomenon; on the contrary it is very general. Hence the general occurrence of pisolitic iron ore in the entire tuff plain, in so far as it embraces the marine tuffs. This is illustrated by what Verbeek had already written:[42] "Between Tangerang and Serang, sometimes for a distance of kilometers, use is made of darker, nearly black and reddish brown iron-stone for surfacing the post road. This iron ore occurs in thin blocks on the pumice stone tuffs and is not limited to the boundary with the alluvium,[43] but is also found on the little plateaus at 50 to

38. For the distance between the Danau volcano and the Tjisadane = about 60 km., with an ocean depth of about 150 m. and a current speed of 2 nautical miles per hour, ash particles as small as about 60 mu would be able to sink, but certainly smaller sizes could not.

39. Verbeek and Fennema, l. c., p. 874.

40. J. Th. White, Agrogeologie der Way Lima-streck, Meded. Alg. Proefst. Lb. No. 19 (1925), pp. 10-15 in particular. E. E. Scheibener, Petrogr. Resid. Bantam, Meded. Alg. Proefst. Lb. No. 18 (1925), pp. 117-146.

41. See pp. 560-561 of this book.

42. Verbeek and Fennema, l. c., pp. 877-878.

43. Senile, iron-rich alluvium, originating from the younger material, richer in basic rocks, lying in the Southern Mountains and carried out and deposited upon the tuffs.

60 m. above the sea." It seems to me that these little plateaus may be reconciled with the above-mentioned small depressions from the time when the tuffs first rose above the sea; perhaps these plateaus also originally had alluvium lying on them, but that was then later; with a further rising of the land and a simultaneous cutting down deeper of the rivers, any loose material was again eroded, while the harder and heavy masses of iron oxides now remain lying capping the elevations. These lumps of iron ore are called "batoe bangkong."[44]

Still another statement by Verbeek deserves to be mentioned here; and by way of introduction it should first be stated that when the sea retreated, even to such an extent that the bed of the entire Java Sea became dry,[45] the climate of the North Coast of Java must unquestionably have been drier than at present, at least during the east monsoon. Now with an annual rainfall of about 1,600 mm. the number of "dry" months for this region between Anjer and Tandjong Priok is from 1 to 3. But if, for example, the rainfall should decrease to 1,400 or 1,200 mm. then the number of dry months could easily rise to 3 or 4, which would mean a dry season like that which is usual along the north coast of East Java. But then the climatic conditions would be such that in addition to iron concretions calcium carbonate concretions would also develop. As Verbeek wrote:[46] "Close to the boundary of the white, Quaternary tuffs with the dark alluvial clay of the sea coast....the covering of marine clay is still very thin and most of the water channels between the paddies are dug down into the tuffs. At a number of places northwards from the post road between Serang and Kopo[47] in place of clay thin blocks of a very special sort of lime are found lying directly upon the tuff layers. The blocks consist of kidney-shaped pieces usually porous or pitted on the outer surface....without a trace of organic structure....consisting of the coarse sand of the tuffs, cemented together with a profuse calcareous cement." Precisely the same phenomenon, but upon much younger base formations, I have observed in East Java, behind Probolinggo.[48]

Just as to the south of the older Danau volcano there has grown up a quite large complex of younger volcanoes all of exclusively more basic rocks, likewise also to the north of Danau is a small volcanic complex, the Goenoeng Gedeh. This fact in itself would not be worth recording here except that on the eastern side of its foot and extending all the way to the coast this mountain, likewise consisting of basic rocks, has a better soil than the more distant north coast of Bantam. This is apparently the reason why with a rainfall of not even 1,600 mm. per year and a distinct dry season, cotton is planted here,[49] even though the farmers raise the fiber only for their own use. Toward Tjilegon some sugar cane is also planted for home use. But neither crop is planted farther east in the low plain of Bantam.

* * * * *

The mountainous lands of southeastern Bantam, together with the mountains lying to the east therefrom, approximately enclosed within the highways connecting Rangkas Betoeng--Djasinga--Buitenzorg, Buitenzorg--Tjibadak--Pelaboean Ratoe include for Java a fairly great variety of formations geologically, and rocks which are also petrographically different.

On account of the occurrence of a couple of granitic massives as well as Eogene sandstones and Neogene pumice-rich tuffs, in general character Southeastern Bantam is related to Sumatra. Rutten[50] remarked "that the uppermost tuffaceous section of the Tertiary in Bantam is clearly the equivalent of the Upper Palembang layers [of Sumatra]. For the region

44. A. C. Koorenhof, Jaarversl. (Ressort Bantam), Landb. Voorlichtings-dienst 1916, p. 2 (1918).
45. G. A. F. Molengraaff, Geol. d. Zeeën v. Ned-Indië (Leiden, 1921).
46. Verbeek and Fennema, l. c., p. 877.
47. On the map the village name "Kragilan" has now replaced "Kopo."
48. Compare also, p. 189.
49. See: Jaarversl. Landb. Voorl. Dienst 1916, pp. 4, 8 (1918) and 1919, p. 9 (1920).
50. See L. M. R. Rutten, Voordr. Geol. Ned. Oost-Indië (1927), p. 383.

Photo by the Forest Experiment Station

Fig. 201. Bantam. A vast cogonal (Imperata) plain, the result of repeated burnings and kaiñgining on poor, pale tuffs.

to the south of Rangkas, where these layers of tuff occur as soil-forming materials, the climate also does not differ much from that of Central Palembang and Djambi. But that in itself is no cause for rejoicing, since there is evidently a great similarity between the soil types of this region and those of the higher "talang" of Palembang. This similarity further appears to be true with reference to the following points: formation of pale brownish red lixivium, physically not bad for the vegetation, at least as to water movement and water supply, but chemically poor, especially as to phosphorus. It is also not rich with respect to potassium and magnesium. Its calcium content varies. In the "Tjimantjeur layers" of Koolhoven[51] where between the tuffs are accumulations of shell lime, it is calcareous. On the other hand in the "volcanic Pliocene" where "fossil occurrences are lacking," there is little lime. Considering everything, it is clear that rubber is the only suitable European plantation crop for these soils derived from tuffs, and rubber will do very well, while the natives raise crops in kaiñgins, a practice which the authorities not only have not been able to stop altogether, but which they have attempted to confine to certain areas.[52]

The southwestern part of Bantam and the adjacent southern Preanger is the most thinly populated part of Java (see Table 120, page 574). By contrast on the islands of Java and Madoera, in about 400 of the districts, there are none with less than 80 persons per km.^{2} (these figures and similar ones farther on have been taken from the extensive 1930 Census, Parts I, II, and III).

Of these districts the first four lie in southern and southwestern Bantam, the other five in the south of the Preanger. Tjibalioeng is by far the most thinly populated. There must be a reason for this,

51. W. C. B. Koolhoven, Toelichting bij blad 14 der Geol. Kaart van Java (1935), pp. 33, 37.
52. Cf.: de Memories van Overgave, Res. Bantam van: J. A. Hardeman, (April 1906), pp. 42-43; F. K. Overduyn, (Mei 1911), pp. 54-57; J. C. Bedding, (Maart 1925), pp. 40-42.

Table 120

NUMBER OF INHABITANTS PER SQUARE KILOMETER IN SOUTHWESTERN JAVA

Tjibalioeng	20.1
Tjilangkahan	46.6
Paroenkoedjang	66.4
Lebak	79.3
Djampangkoelon	64.1
Sindangbarang	42.0
Boengboelang	57.4
Pameungpeuk	55.3
Tjidjoelang	79.4

and it seems to me that we must look for it in the soil and the climate. As to the climate, none of these thinly populated districts ever has a dry season. The soil is exposed to continuous and intensive leaching. Even at first the parent material was not rich; continuous leaching has made it still poorer.

As to the parent material the following notes are of interest. On a foundation of solid rocks, breccias and finer fragments andesitic and basaltic in nature, which apparently were washed clean of the overlying ground during the gradual submergence under the sea, tuffs mostly marine were spread out in late Miocene, Pliocene and Pleistocene time. These tuffs were of an acid character with much pale pumice stone glass. As long as and in so far as these lay under the sea, though they were markedly altered chemically, they were not strongly eroded. When they finally came above the water they formed a cover rich in silicic acid and more or less silicified, a material which only slowly weathered to soil. Now and then these pale silicified tuffs of the now low, rounded hilly land, were contaminated, if one may use that word, by incidental rains of ash during the time of their formation under the sea, as well as afterwards during the period of their weathering. This fragmental material was for the greater part of more basic nature, with a greater content of basic feldspar and dark minerals such as hornblende, augite, and hypersthene. There was finally the eruption of Krakatau in 1883. Here, on Java just as in the Lampongs of Sumatra, the resulting ash must have had a rejuvenating and improving effect upon the soil. But this last eruption occurred in August, that is in the time of the strong east monsoon. This explains that while according to Verbeek[53] Telok Betong, Sumatra, was covered with a layer of ash approximately 200 mm. deep, the Vlakke Hoek with an equal amount, and even 50 mm. at Kroëe; in Bantam but 40 to 50 mm. was measured at Anjer, 30 mm. at Tjimonas, 15 to 20 mm. at Rangkas Betoeng, while in the Lebak district the depth of ash on the level averaged only 15 mm. Moreover, it should be remembered that toward Bantam the ash was blown back eastwards by the high counter-trade winds, so that all the coarser ash had already fallen to the west before such material as reached greater heights began its journey eastwards. Thus that portion of the ash reaching Bantam was finer and richer in glass but poorer in those crystals which bring to the soil K, Ca, and P. Hence it can be understood that even after the great Krakatau explosion, South Bantam remained sleeping economically, while the southern Lampongs of Sumatra were revived and rejuvenated.

To those who have not had the privilege of seeing the land itself, the topographic maps of southwestern Java tell a very clear story regarding this matter. On the west side of the very rough and steep Hondje mountains the fresh ash was washed off toward the west coast. Near the small villages of Tjipining and Tjikawoeng are to be found a few paddies, but nowhere else near that mountain, which itself is entirely uninhabited. The Tjibalioeng sheet of the 1:50,000 map does not show a single paddy and, aside from a few small villages along the few roads, only uninhabited land, at most long abandoned kaiñgins with only cogon (see Fig. 201, page 573). Still further east there is still the same abandoned landscape until near Malimping, where there are some paddies. These paddies are in drainage basins of small rivers which have their origin in mountains lying to the east and northeast of Malimping, where there are rocks of all kinds, which while they do not give first class fertility to the soil and to the

53. R. D. M. Verbeek, Krakatau (1885), pp. 127-128.

irrigation water yet they give somewhat better crops than the pale tuffs are able to produce.

If we compare with this detailed topographic map the Tjiteureup and Laboean sheets along the Peperbaai, then the former shows the same forlornness as sketched above, but the more northerly one goes the better the country becomes. Not only did more and better ash fall in 1883, but also beyond the Tjiboengoer there are the drainage basins of rivers which rise in the vicinity of the Poelosari and other volcanoes with basic eruptives, to the south of the Danau. There all the land is used for paddies and around Menes the population is dense. Subsequently, because of the pressing need of arable land and with the help of the modern agricultural technic (appropriate fertilization), in the next few decades the marshes along the Peperbaai will be encroached upon more and more and will be converted into (marsh) paddies. But then the encroachment will be in an unusual manner, not gradually in from the coast and the road which runs along that way, but rather down from the north, from the landward side. However it will still be a very long time before settlers moving southward will reach the hilly land and the south coast.

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The farther one goes eastward, the more the mountains of southeastern Bantam are made up of respectable volcanoes built up of more basic rocks, among which andesite and basalt predominate. On the boundary between Lebak and Buitenzorg there lies a complex of volcanoes which includes the Goenoeng Halimoen and the G. Sanggaboewana, both more than 1,900 m. high. More southerly is the G. Pangkoelahan (1,768 m.) and still another G. Halimoen (1,750 m.), while somewhat toward the east-northeast is the group to which the Salak (2,211 m.) belongs. The first mentioned complex is today considered to be of Pleistocene age,[54] while the geologic age of other volcanoes has not been more definitely stated than as "mostly Pliocene-Quaternary."[55] However only a few of the volcanoes, because of their recent activity, can be called Quaternary, but this does not deny that even these might have commenced their activity as early as the Pliocene.

As a consequence of the greater basicity of the ejecta of these volcanoes, another type of weathering has prevailed, giving better, more fertile soil types; and thus also more paddies, more upland or mountain crops, and so more population. Considered by itself the natural fertility of most of the paddies in the Djasinga, Leuwiliang and Buitenzorg districts is not notably high, and the content of the principal plant food substances in these paddy soils is definitely low, but there are two factors which make these soils better than the Bantam mountain lands farther to the west. In the first place, a soil poor in phosphorus is better than one with practically no phosphorus at all. Secondly, all soils, and this includes the paddy soils, which have been entirely or to a large extent derived from the Bantam tuffs, contain quite a high percentage of silt. This is an acid volcanic glass, in part silicified, weathering only with difficulty. It is a material which greatly retards water movement in this soil, making it difficult for the vegetation to obtain adequate supplies of water and plant food. This condition also tends to increase soil acidity. This tendency is especially noticeable in soils which contain relatively much pale clay. Because of all these reasons it follows that on these Bantam soil types in a single year a second crop seldom does well, consequently a second is seldom planted. On the soil types in the mountainous land lying more to the east, however, if one does not wish to follow one crop of paddy with a second crop of paddy which can also be done, all kinds of vegetable or upland crops can more easily be planted. "But not much is really produced" wrote the Resident of Bantam in 1906.[56] Having passed the boundary, however, the more easterly we go, the less frequently do we find the paddies lying idle during the east monsoon.

54. W. C. B. Koolhoven, Sheet 14 (Bajah) of the Geological Map of Java (1932).

55. L. J. C. van Es, Geol. Overz. Kaart. N. O. I. Arch. Blad XV: Jb. Mijnw., (1916), Verh. II., pp. 55-140.

56. Hardeman, l. c., p. 41.

The following figures[57] (Table 121) from five districts, located in a row from west to east, demonstrate very clearly what has just been said. While the climate and the elevation do not differ much, the parent rocks gradually change from relatively acid in the west to more basic in the east; more and more land is cultivated, more and more paddies have been laid out, and the population naturally is not so sparse.

In so far as there is still a question of unirrigable, hilly, rolling lowland, consisting of the repeatedly mentioned Bantam tuffs, we can expect little else of them than what we have already seen on the same parent material south and southwest of Rangkas; namely, a little upland cultivation, a little forest, with here and there some rubber. Some cattle are pastured upon these lands; but most of the region lies unutilized (see Figs. 198, 200-201, pp. 569-573).

Table 121

RELATION OF ROCK TYPE TO LAND UTILIZATION AND POPULATION

District	Rock Type	Agricultural land	Paddies	Upland unirrigated	Population per km.^{2}
		% of the whole district			
Lebak	Relatively acid	16.7	6.7	10.0	79
Djasinga		22.6	10.5	12.1	123
Leuwiliang	Intermediate	29.9	24.5	5.4	260
Paroeng	Relatively basic	74.8	34.1	40.7	393
Buitenzorg		67.3	40.1	27.2	540

It is obvious that with improvement in the nature of the parent rocks from west to east there is also a parallel improvement in the irrigation water for the paddies.

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The nature of the soil of the low plain to the north of the line connecting Pandeglang, Rangkas Betong and Depok is determined predominantly by two things: (1) Whether or not it is possible to use for irrigation the water from the rivers which rise in the mountains lying to the south of the line mentioned and which flow out toward the north. (2) In case there is the possibility of irrigation and/or natural flooding of the land, the nature of the water and silt of these rivers markedly affects the soil. This is influenced by the parent rocks and their degree of subdivision (massive rocks or tuff), the ways in which weathering has taken place, and the stages of weathering of the mountains which lie behind.

The irrigable terrain, partly the lowest east to west strip of the Bantam tuffs, but mostly the alluvial low plain, lying in thinner or thicker deposits upon the substratum of these tuffs, is as a while utilized for paddy cultivation. Along the north side the paddies sometimes extend right out to the sea. But where the soil is too salty the land has been left as swamp forest or has been used for the construction of fish ponds.

Regarding this extensive paddy plain, from about Tjilegon to close to Tangerang, it can be stated that because of the skill and care of the inhabitants it is handled well. If the farmers do not neglect the irrigation, harvests are obtained which are better than the average for Java. And this in spite of the fact that the soil is poor, especially where the irrigation water has its origin entirely or for the greater part in the tuffs. Especially as to the phosphorus both soil and water are sometimes so extremely poor that without fertilization almost nothing is obtained, while with superphosphate a good harvest may be gathered. From a "review of the results of fertilizer tests in the

57. Taken from the data of the 1930 Census and the Landbouwatlas v. Java en Madoera, II: Tekst (Weltevreden, 1926).

subdivision Serang during 1918-1919"[58] have been taken some data which are set forth in the following Table 122:

Table 122

Name of the experimental fields	Paddy yields in quintals per hectare	
	Unfertilized	Superphosphate 1.74 quintals per ha.
Poelo	1.2	22.5
Tjiroeas	2.4	32.3
Tjinanggoeng	16.3	33.1
Sidapoerna	21.3	40.1
Kapoeren	33.5	42.2
Panglawad	42.8	50.8
Djami	46.2	51.5
Panantjangan	49.6	53.5

All the experimental fields, from the least to the most productive, lie on the same soil type, named by the Soil Science Institute "Bantam tuff loam." It is apparent that this type gives a clear response to P fertilization; on the poorest soil the effect is astonishing. Honesty demands that we add that on a few experimental fields superphosphate gave no effect, or even a negative one. Treated in a similar way the yield of Kalanggaran field was increased from 40.2 to only 40.8 quintals paddy per hectare; Soemoer Asem was reduced from 36 to 35.3 qu./ha.; while the Keben field showed a greater decrease, from 40.2 to 37. qu./ha. But it should be kept in mind that all three of these experimental plots lie close to Serang, while the others are almost all more easterly, lying around Tjiroeas, which is evidently a center of P deficiency. Around Serang, on the contrary, apart from the possible affects of the town, probably soil and irrigation water are influenced by the proximity of more basic rocks (from the Karang northwards to close to Kramatwatoe), as expressed in a small or in no deficiency of P.

Close to Tjiroeas is the Singamerta permanent experimental field. From half a dozen seasons' tests it is apparent that there the typical Bantam tuff loam not only is deficient in P, but is poor as a whole (see Table 123 below).

Table 123

APPROXIMATE AVERAGE YIELDS IN QUINTALS DRY PADDY PER HECTARE			
Unfertilized	Nitrogen	Phosphorus	N + P + K + Ca
about 10.4	about 13	about 23	about 27

The following experiment[59] upon the lixivium derived from the Bantum tuff is also striking. This soil close to Njapah village, in the sub-district of Walantaka, is called by the Soil Science Institute "brown, sharp, sandy, quartz-rich laterite soil." There was here no paddy land, but an upland rice culture. The rainfall was inadequate so that the crop because of a lack of water did not do as well as it might have. The unfertilized plots gave but 1.6 quintals paddy per hectare, by the use of barnyard manure this was raised to 7.2 qu./ha. The use of ammonium sulfate alone, however, gave only 2.5 qu./ha. (P in the minimum). Ammonium sulfate with double superphophate gave 12.5 qu./ha.; ammonium sulfate and potassium sulfate (thus without P) only 2.9 qu./ha. But ammonium sulfate plus double super plus potassium sulfate gave 16.8 qu./ha., and by an addition of lime this figure was raised to a yield of 19.5 quintals dry (upland) paddy per hectare.

Although in none of the experiments of the series of the Agricultural Institute, neither those here recorded nor many more which I have not here specifically referred to have there been given figures for the analysis of the soils of the corresponding experimental fields. Yet the practical results indicate very clearly where the deficient areas are and what yields one should be able to obtain with appropriate fertilization on these poor tuff loam soils.

Further east, for example around Maoek, the alluvial plain is not so poor. The rivers Tjidoerian and Tjimantjeuri, and

58. Jaarversl. Landb. voorl. dienst (1919), p. 13 (1920).

59. Cf. Versl. Bemestingsproeven, West moesson 1930/31, No. B. 236, Landb. Inst. v/h. Alg. Proefst. v/h Landb.

especially the Tjisadane, provide both better silt and better water. Furthermore, without doubt the sea improved the deeper alluvial layers at the time of their deposition in sea water. Finally the climate there has an intensive dry season; all these are reasons for greater fertility. As a consequence, few researches relating to the soil and its productivity have been necessary in this region; hence plot experiments have not yet been carried out. However, this stretch, like the whole low plain from Tjilegon to Tangerang, needs to have a certainty of harvest. This means security against drought, as well as against floods, which can be achieved through technically well-regulated irrigation. For North Bantam the Tjioedjoeng works have now taken care of this. But in the district of Northwestern Batavia there is still a great need of overcoming the lack of water during droughts as well as also to get rid of the souring of the soil, reduce the mentek disease of rice, etc., by properly developing irrigation from the above-mentioned three rivers, while not forgetting to provide for proper drainage of the low, marshy places, where there are annually still a number of partial or complete crop failures.[60]

When these engineering works are ready, then will be the proper time to take advantage of suitable fertilization, both for lowland rice as well as for the supplementary crops. "From a second planting of paddy irrigated with water from the Tjioedjoeng River, but without fertilization no decent crop is to be expected" Resident de Kanter[61] wrote in 1934. Also for Balaradja, Maoek and Tangerang we may expect the same effects although to a lesser degree! For although Tangerang is certainly the least in need of fertilization, even there it will doubtless be very effective.

Within the Tangerang district, southwest from the bay of Batavia, running over the peculiar Kamal region, there is also a region which shows very clearly a dune ridge formation. While not all of these ridges are irrigable, yet they are not so high but that the numerous cocos planted on them are able to obtain adequate water. The low strips between the ridges were previously occupied by a swamp forest. These depressions have now been completely converted into paddies. The inhabitants live on the ridges under the palms which bear good crops of coconuts, for the sand of the dunes, which for a large part was carried down by the Tjisadane and Tjiliwong rivers toward the sea, is volcanic, thus good fertile sand, that gives rise to a fertile soil. Only a narrow strip along the sea is too low and muddy for agriculture. In this strip are fish ponds and part of it is occupied by mangrove forest right up to the city of Batavia.

* * * * *

The Salak complex of volcanoes and the still much greater Gedeh-Pangeranggo complex have together supplied the building materials for the soil of the entire strip lying north from these volcanoes and extending on out northerly to the sea coast. Most likely since the Pliocene down until the most recent times, geologically speaking, mighty ash eruptions and mud flows have probably alternated with each other in covering up everything. Viewing these activities from the standpoint of soil science, however, these mighty activities took place long ago, for in the surroundings of Buitenzorg, for example, the soil lying on the surface is already a reddish brown lixivium, senile to a high degree. The last great volcanic eruption which took place seems to me to have been the bulging out of the north-northeastern part of Salak crater, coupled with great mud flows down what is now the Tjiapoes valley (see Fig. 202, page 579). For example in the extension of that valley out into Tjimonas is a sharply defined very juvenile lahar mud flow field, made up of sharp andesitic sand with large, fresh rocks in it. Even the sand in that field is but very slightly weathered.

Under the reddish brown lixivium around Buitenzorg at a depth which varies from 1 to 3 m., there is a pale layer,

60. Cf.: J. C. Bedding, Memorie Res. Bantam (Maart 1925), p. 7. Jaarversl. Landbouwvoorlichtingsdienst (1916), pp. 2-5.

61. J. S. de Kanter, Memorie Res. Bantam (Mei 1934), p. 117.

Photo by Hj. Jensen

Fig. 202. Above Buitenzorg, near Soekamantri, West Java. Remains of the lahar from the caving in of the crater wall of Mt. Salak (note the cleft). Mountain slopes completely covered by tropical high forest. In the foreground the bed of the Tjiapoes river, a mass of andesitic boulders.

yellow when damp, and dingy grayish white when dry. This horizon which at Buitenzorg is approximately 2 to 3 m. thick, toward Tjileboet decreases to 1 dm. and less, and up against the Gedeh disappears entirely, while against the Salak, especially on the northern slope, it is even 3 m. thick and more. It is clear that this material was originally a colorless pumice stone, in which were phenocrysts of brighter plagioclase (andesitic), some limonite dust, and a little hornblende. In the lower land much of the pumice stone has been weathered to a pale clay. Higher up however, more of it remains unweathered, in spite of the fact that here at greater elevations the pale layer, through the disappearance of the overlying layer of brown lixivium, has been more and more exposed. In this connection it may be mentioned that regarding Kiara bèrès (on newer maps named Goenoeng Awibengkok) a volcano lying southwest of the Salak, between the Goenoeng Perbakti and the Goenoeng Gagak, Verbeek and Fennema[62] stated that "The Kiara bèrès has erupted only glassy rocks. Close to the summit are found weak tuffs and very brittle, sandy pumice stone of a light yellow color which is easily broken with the hand." The report also mentions "more solid pumice stone" and "an obsidian flow which consists in part of darker, and in part of white obsidian." It seems probable that these obsidians and pumice stone tuffs are related to the pale ash which occurs in the soil even beyond Buitenzorg. Besides this, the material forming the land which gradually slopes toward the north becomes andesitic.

At about opposite Depok, or somewhat more south, there is a line, to the south of which the soil can be called brown, or at most a reddish brown lixivium, but to the north of this boundary, however, the color is definitely a red, or at least somewhat brownish red. The change is sharp.

62. Verbeek and Fennema, l. c., p. 498.

According to Frontispiece A, the soil south of the boundary is in stages 3-4, and that to the north is in stages 4 to 5. In the terrain to the north in deep profiles exposed, for example in deep cuts of irrigation canals, there are clearly visible under the red surface soil the red flecked, pale clay horizon and still deeper the old mud flows, cemented to tuffs by a silicious cement.

There are two ways in which we may explain the marked soil differences which are so apparent along the road between Buitenzorg and Batavia. If it be accepted that both types of deposits are terrestrial formations which have been subjected only to subaerial weathering. We must admit a long lapse of time between the deposition of the two sorts of soil material, thus an interval of rest between the mud flows, and so in the volcanic activity of the Salak and the Gedeh. It is quite possible that the oldest mud flows, those which have pushed out the farthest toward the north, are of Pleistocene age, while the younger, those which did not flow out so far are more likely Subrecent or Recent. If, however, one lays weight upon the fact that the red soil type occurs only above about 100 m. elevation and, as has been mentioned above (see page 570) that in the time of greatest activity of the Danau volcano the sea stood about 100 m. higher, then we might suppose that also the older mud flow fields from the Salak and the Gedeh were either deposited in the sea or, after their deposition, had been subjected to a bath in the sea. It thus comes to the same thing, namely, either the marine tuffs themselves had been submerged or after being weathered to brown soil, the material was submerged in the sea. And according to an hypothesis[63] first proposed in 1930, this treatment would be quite enough to bring about the dehydration of the iron hydroxides, thus to develop a red color. Only thorough research in the field, coupled with laboratory research along many lines, in short a soil survey, will be able to prove or disprove this hypothesis.

To the north of the red soil type and extending on out to the coast is a gray type of soil. A low terrace face or escarpment, of at most a few meters height, separates the two types. Contrary to Verbeek's supposition[64] this gray coastal strip of soil, in some places narrower and in others wider in the north and south direction is not a much more recent alluvium, as contrasted with the red, older Quaternary soil material but is rather a gray, subaqueously weathered soil type. On the contrary, the gray soil has been formed from the same material as the red; only the latter was subaerially weathered, i.e. it remained above sea level. Before man commenced to use all of these lands the continuously submerged soil was covered with swamp forest, quite similar to that which now occurs here and there around Tandjongpriok. Later the swamp forest was converted into paddies, so that the soil remained more or less under subaqueous conditions; at most it became more amphibian. Thus the gray color also persisted, though perhaps somewhat more brown flecked or veined in the dry season. Even though the population became denser, more paddies were not cultivated on the higher, red lands. But where the elevations of the terrain were only small the paddy cultivators nibbled at them, and gradually worked them down to the lower level. Thus the blows of the cultivators' hoes acted like the abrasive foce of the waves on a sea coast and developed what might be mistaken for a wave cut terrace along a sea shore. Whether or not there was originally a small natural terrace here, I cannot say, but I am sure that the above-mentioned terrace was produced artificially in the way described.

It is very likely that in earlier times the gray north coast soils were for the greater part submerged under sea water or brackish water. At present, however, it is only the coastal strip in the narrow sense which is still muddy. A large part of the material out of which the plain has been built up and which had been carried out by the rivers from the hinterland was andesitic ash and fine sand. So long as sea water or brackish water covered the

63. E. C. J. Mohr, Tropical soil forming processes and the development of tropical soils, (translated from the Dutch by Robert L. Pendleton), (Peiping, China, 1933), p. 37.

64. Verbeek and Fennema, l. c., p. 501.

soil, the pH obviously remained above 7. Even later, when that salt water was gradually replaced by fresh water the opportunity for the development of acidity was small. This was because there was still much material in the soil which was far from being weathered out, so that it was not possible for all the bases to be washed out from the soil. Hence the reaction could not soon become acid. The consequence was that peat, oligotrophic peat, could not form. While between the Bantam tuff layers one finds peat, neither between the Batavia tuff layers nor in the Batavia "swamp" is any peat to be found. In the course of time the gray soil has been pretty well leached out, but not even yet has been so strongly leached as the somewhat higher lying red soil. In the red soil,[65] however, the pH is still not lower than 5, hence in the gray soil the pH, in all probability, will not be lower. The pH is thus still too high for the formation of peat.

If we now stop to consider how in the districts of Tangerang, Kebajoran, Meester Cornelis, Tjibinong and Buitenzorg agriculture is carried on, then the first thing we notice is that as much as possible of the land is irrigated. But even in this respect much more improvement can still be made. And for this purpose the Tangerang works, among others, have been projected. In these districts there is not so much a question of the lack of water or the disadvantages of irregular, long continued dry periods which may occur, as that of the fertilizing action of the irrigation water. It is indeed true that the plant nutrient content of the water of the Tjiliwong, for example, is not high and certainly much lower than that of such a stream as the Brantas,[66] yet as a rule there is much water available so that the rice plants in the paddies can still get the necessary quantity of food materials. In itself the soil is in no sense rich; the older, lower red lixivium is poorer than the brown soil higher up. On the brown soil, without irrigation, only a limited number of crops are possible, and still fewer on the red. But if the land be planted to rice and irrigated in the west monsoon, then in the east monsoon on the brown lands higher up (more rain) all sorts of second crops can be grown, especially turnips and legumes. While in the zone of the red lands it is more difficult to do this, yet it is possible, though often only with very poor results.

As is the case in a number of other regions of the Archipelago similar to this, on the unirrigable lands which are poorly supplied with the plant nutrients, but physically in no sense bad soils, we note tree crops and because of being close to the large centers of population, Batavia and Buitenzorg, there is a very considerable cultivation of fruits. Begun incidentally in door yards, the plantings have been developed into a more orderly and extensive cultivation and at present even to regular orchards, in which not only undergrowth and fertilizing play a part, but varieties are even selected for quality. In addition to all sorts of village waste, stable manure was the usual fertilizer before the advent of extensive automotive transportation. But now, since horses and hence farmyard manure have become relatively scarce, the use of commercial fertilizers is increasing (in so far as the yields justify the expense). Green manures are also used. But both these last two western aids to fruit culture are still far from being generally accepted practices.

Nor is the question of fertilization at all simple, because here there is no pronounced deficiency of a definite nutrient, for example, phosphorus. This is just opposite from the condition in Bantam. Fertilization here is rather a many sided question. For example in addition to poverty in N and P there has been established a definite lack of K,[67] while Ca and Mg, as well as humus, especially "living humus" are to be desired. Thus a few years more will still have to pass, before there will have been found for the different cultivated crops and trees the particular fertilizers which are the best and most economical and hence to be recommended.

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65. Cf.: J. Th. White, Versl. 13e Vergad. Vereen. v. Proefst. Pers. (Oct. 1933), p. 31.
66. See: L. G. den Berger, and F. W. Weber, Water en Slibonderz. v. versch. riv. op Java, Meded. Alg. Proefstat. v/d Landb, No. 1 (1919), Table 1 ff.
67. Cf.: J. Th. White, Kali, en phosphorzuurbemesting op oude laterietgronden, Landbouw, IV (1928-'29), pp. 143-170. Analyses, p. 145.

Pretty much the same conditions prevail in the western halves of the districts of Tjibaroesa and Bekassi, lying to the east of the districts we have been considering. Parent material, soil, and climate are exactly the same. However, on the eastern side of the Tjileungsir and the Kali Bekassi rivers the soil does change.. North from the Gedeh complex particularly older, Miocene and Pliocene, rocks begin to form the foothills of the mountainous region. These are the rocks which, the further one goes east, especially in Central and East Java and Madoera, come to play a continually increasing role in soil formation. Apart from volcanic, mostly Pliocene or still younger constituents of the mountain (tuffs, mud flows, and sands, for the greater part of andesitic nature), the Miocene rocks include quartz sandstones, coarser and finer marls, claystones and limestones. As already described more in detail above (Part I, and also in Part II), these rocks differ markedly from the volcanic rocks of the regions here being considered, because upon weathering to soil they leave behind a great quantity of quartz sand and quartz powder (this latter particularly in the loams). Moreover, in general these rocks contain a much smaller quantity of iron, a constituent which in the course of subaerial weathering leaves behind in the soil compounds coloring it brown or red and at the same time making the soil very much looser and more friable.[68] If the view expressed previously (pages 526-527) be correct, the clay in the soil coming from the marls must be predominantly montmorillonite and not kaolinite; the high plasticity and the great capacity for swelling and shrinking which this heavy, sticky clay exhibits, leads me to believe this to be the case. Fine quartz powder mixed throughout the clay, however, makes it a tenacious heavy loam with less shrinking and swelling. Upon drying of clods in the air the fine crumbly ("cauliflower") structure becomes less and less conspicuous, and the soil forms larger and larger stone-hard chunks. Finally with still more quartz dust and quartz sand only very few cracks develop in the soil and in the extreme case of sandy types the cracks are absent and the plasticity and stickiness are also lost. But in West Java the change does not often go as far as this; for marls and tuffs greatly preponderate over the pure quartz sandstones.

Thus to the east of the Kali Bekassi River the soil of the paddies gradually begins to become heavier. The slight increase of iron compounds, which is found under almost all of the paddies which are not entirely too light, is indicated by distinctly rounded and hard iron concretions. The color becomes bluish gray and except in the uppermost millimeters the soil contains so much iron in the ferrous form that with a crystal of red ferrocyanide one can easily write his name in bluish black color on a fresh cut surface. Such phenomena are found especially along the Tjibeët River, but the Tjileungsir, the Tjikarang, and the Tjipamingkis Rivers also carry off marl silt, although it contains a large proportion of volcanic silt from the Gedeh complex. The great Tjitaroem river does the same but since the upper portion of its drainage basin lies between or on the slopes of great volcanic complexes this river also carries with it large amounts of volcanic soil material toward the northern Krawang plain.

In connection with the large project at present being carried out for the irrigation of the entire plain which lies roughly between the lower course of the Tjitaroem, the road and railway connecting Gedonggedeh and Tjikampek, and the highway from Tjikampek to Tjilamaja, a number of researches are being carried out on the soil of this great tract of more than 80,000 hectares. From these studies it has been found that the soils of this plain are in no sense homogeneous. For example there are portions north of Krawang which contain quite a good deal of fine quartz sand and quartz powder, as they are rather a heavy, pale loam. While other parts, for example about Lemahabang, are richer in clay and are either a looser, red lixivium, or a darker gray paddy clay. If a soil survey could be made of the remaining reservations, so that all these differences could be indicated on a map, it would be very important in connection with the productivity of this soil as paddy land, which has been well known for years, as well as being useful in connec-

68. Cf.: p. 131.

tion with the test cuttings of the tax assessors.

That in addition to much fine silt, the Tjitaroem also carries sand toward the sea is apparent from the building up of the northern coastal plain. Of course the main movement of water and silt does not occur in the east monsoon, but during the west monsoon, for with the winds from the west a current sets from the west toward the east along the coast. From the time that the Tjitaroem flowed into the sea approximately at Rengasdengklok, the clay must have flocculated out in the sea and the sand settled to the bottom east from the mouth, being carried by the currents from the west. As a result the mouth of the river has been deflected toward the west. Without this sea current the river would have built out a delta toward the north-northeast. Now as the clay settled to the bottom out from the shore and in the mangrove forest along the coast, the vegetation advanced farther northwards. The sand grains, however, as a coastal sand bar, were rolled farther on and were thrown up on the beach between Tjemara and Tjilamaja; a locality where the coast faces toward the east-northeast. Here the dry winds of the east monsoon strike the coast and blow the dry sand up into sand dunes[69] just as the sand of the Tjisadane is blown into dunes along the west coast of the bay of Batavia (see page 578). Only here the sand is farther away from the mouth of the river, and thus there is less of it. Apparently for a long time the Tjimanoek has not carried any sand, otherwise there would have been more of it thrown up and blown up into dunes along the coast between Indramajoe and Cheribon. If, however, the Tjerimai or other volcanoes which belong to the drainage basin of the Tjimanoek ever erupt considerable quantities of ash, then dunes would also commence to form along the coast east of the mouth of this river.

Most of the sand of the Tjitaroem consists of quartz sand from Miocene rocks. As a consequence the ridges northwest of Tjilamaja are not so fertile as those lying west-northwest of Batavia. Cocos are growing on these dunes, but also much bamboo, which the inhabitants are indeed in need of, because of a lack of other building materials and fuel. The extensive treeless plain behind these dunes has been entirely converted into paddies. At one time there must have been one great swamp where now--south from Lemahabang--still just a little is left. The rivers which flow through this swamp during spates deposit upon and behind their banks low, sandy ridges. On those higher spots the inhabitants now live.[70]

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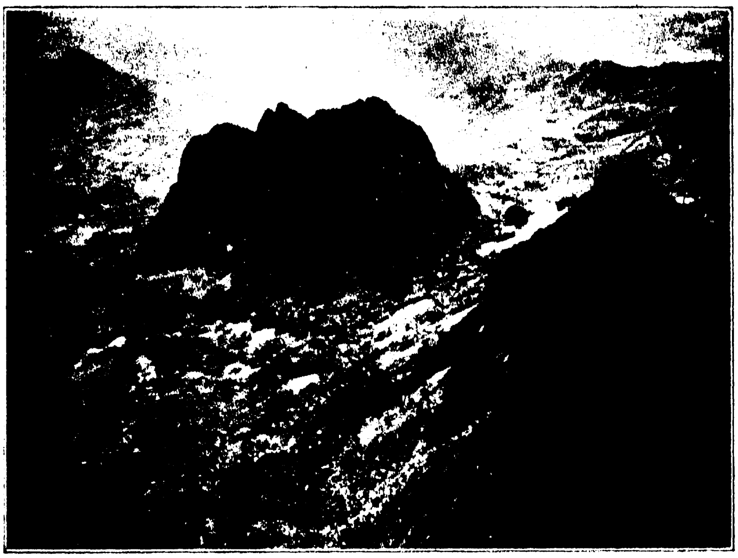
Between the Gedeh complex and the soon-to-be-considered Tangkoeban Prahoe complex of volcanoes, north from Bandoeng, there lies a lower mountainous land, which extends through the districts of Tjibaroesa, Krawang, Poerwakarta, Tjikalongwetan, Tjirandjang and Patjet. In this region there are especially to be differentiated[71] the volcanic Sanggaboewana mountains consisting for the greater part of hornblende andesite; while east from them is the volcanic mountain Parang, likewise consisting of hornblende andesite and allied rocks. There is also much Miocene hilly land, of which the Tegalwaroe Region is the largest adjacent portion (see Figs. 203 and 204, page 584).

Although the two volcanic mountains just mentioned have broken through the Miocene layer[72] and are thus younger, they are still already old from the pedological point of view. Where the cliffs still carry soil, forest is standing.[73] But where they are too steep for that, the cliffs are bare (see Fig. 203, page 584), so that out from these two volcanic regions but little soil material is eroded toward the rivers and carried away by them.

69-70. Compare the topographic maps 1:50,000 No. 38/XXXVII B and D, and 39/XXXVII A.

71-72. See sheet 30 of the Geological map of Java (1933) by O. Ludwig with a short agrogeological description by M. Szemian.

73. Forest which is maintained because of its protection of water supply.



Aerial photo by the War Department

Fig. 203. West Java. The Parang Mts. Laccoliths of hornblende andesite stick out above the much weaker sloping, Tertiary sedimentary rocks east from the Sanggaboewana Mts. On the Tertiary materials is miserable vegetation; on the hornblende andesite is forest, especially below on the steep slopes. Where possible the natives have laid out paddies. Smoke in the distance is from burning slash for making kaiñgins.

Photo by Bley

Fig. 204. Tegalwaroe lands, West Java. Rolling land of Tertiary marls, etc. Poor vegetation on a poor soil difficult to handle. What few inhabitants there are are very poor.

Agriculture is carried on only in the more or less flat valleys, not on the steep slopes.[74]

If there is not much to be said of this quite senile, brown to reddish brown lixivium derived from the hornblende andesite, the soil types on the Miocene marls must here receive more attention, since as we are travelling from west toward the east, this is the first time we find these marls on the grand scale and in part unmixed with tuff material. Szemian notes explicitly[75] that the fine sandy fractions of the "brownish yellow quartzitic marl clay soil" are characterized by small "quartz grains from granite, beside which there are also gauconitic substances." From just where in Neogene time this granitic sand had come is not known. This is a question left for the geologists to solve.[76] In this connection the grain size of the quartz grains in the marls, loam slates, and sandstones can also give indications[77] which perhaps deserve more attention than they as a rule receive.

In so far as the climate has no marked dry season, in this region there develops from the "claystones, clay marls, marls, and marly limestones" a "dirty yellow marl soil, poor in quartz" (Szemian). "The permeability for water is low"; the soil thus weathers with difficulty in the subaerial manner. Obviously the higher the ground lies, the more opportunity there is for air to penetrate, the lower it lies, the less. Szemian thus notes: "Reddish tints in this soil are quite exceptional, occurring higher up on the hill slopes. Elsewhere the color of the profile is a dirty yellow to grayish yellow, with increasing depth gradually grading into gray." This illustrates how the presence or absence of air affects the color.

The soil is heavy clay, and Szemian measured a linear shrinkage of 19%. Thus in drying out the soil shrinks in all directions, and to approximately half the wet volume. Since this marl soil always contains more or less quartz dust, which in itself does not shrink, it is evident that the colloidal portion of the soil must have a very great power for shrinking and swelling. Hence we may assume that this colloid is not kaolinite but rather montmorillonite. The mixture of materials which has developed into this soil was originally distinctly alkaline because of the calcium carbonate in the sedimentary rocks. Thus the conditions were particularly favorable for the formation of montmorillonite.[78] On the other hand, granites in a prevailing wet climate, such as for example on Bangka and Billiton, are much more apt to give rise to kaolin(ite). If that was also the case in Miocene or Premiocene time with the material from which these marls were later developed, then this kaolin(ite) must later have been transformed to montmorillonite. Further observations and experimental investigations will have to decide as to which of the three following possibilities is the most probable:

a. In the Miocene rocks kaolin(ite) is still to be found, and during weathering this is transformed into montmorillonite.
b. Montmorillonite is present as such in the sedimentary rocks; for it was formed out of kaolin(ite), after the latter had been carried by the rivers into the sea.
c. From the beginning, as the granite weathered the material had been in the form of montmorillonite. This montmorillonite was formed either (c-1) in the course of submarine weathering, thus in an alkaline system (but this is not very probable, since such quantities of detritus were never available for transport). Or (c-2) through terrestrial weathering under another, much drier climate, so

74. Compare: Szemian, l. c., p. 43, where will be found various details.

75. Szemian, l. c., p. 38.

76. See: L. Rutten, Over de herkomst van het materiaal der neog. gest. op Java, Versl. K. Akad. Wet. XXXIV (1925), pp. 689-708.

77. Cf.: Verbeek and Fennema, l. c., pp. 263-264 (Over de Karimoendjawa-eilenden). E. C. J. Mohr, Bull. Dépt. Agric. Buitenzorg, XLVII (1911), pp. 47-51.

78. Compare pp. 526-527 of this book.

Photo by L. P. de Bussy

Fig. 205. Michiels Arnold lands, West Java. Paddy plain on river alluvium of volcanic material from the high back country (G. Gedeh, etc.) mixed with lime and marl silt from the Tertiary formations in the foreground. The latter are not intensively cultivated.

that at least for a sufficiently long time an alkaline reaction could have prevailed.

Although thus far no facts have been found to substantiate this hypothesis, it seems to me that the possibility suggested under (b) is most likely the correct one. Studies of the sediment of certain rivers of Bangka carrying kaolinite, and of the sediments in the sea off shore from the mouths of such rivers can perhaps throw a little light upon these questions.

* * * * *

In the Tegalwaroe region Szemian[79] also observed two soil types on Miocene limestones; he differentiated them thus: "The limestones of biological origin weather to calcareous black earth, while the tuffaceous limestones give rise to tuffaceous calcareous red earth."--Now according to Ludwig[80] the limestones of organic origin are in part reef limestones, that is from coral, Foraminifera, shells, etc., and in part from calcareous quartzitic sandstones. The former rocks are the parent material for the calcareous black earth, while, if through weathering the lime content of the second sort of rock disappears, the gray color changes into a rusty, yellowish brown (quartz sand). Szemian[81] does not mention the quartz sand, but rather the importance of the clay content. From limestones of organic origin with a low clay content but little soil develops which is rich in organic matter and black in color. With an increase in the clay content the color becomes lighter, and the soils gradually grade into types agreeing with the above already-mentioned marl soils."--"As to the calcareous red earths, with the increase of the clay

79. Szemian, l. c., p. 39.
80. Ludwig, l. c., p. 10.
81. Szemian, l. c., p. 39.

content the color shifts from red toward brown." But regarding this tuffaceous mixture we read that there are "feldspar crystals, green chloritized little grains and fragments up to ½ cm. in diameter, of a glass-rich more or less basic rock."

Whether with the presence of some tuff material the color is not reddish black or brownish black, but is red or brown, and whether with the absence of it from this parent rock, the soil will be a calcareous black earth, is as yet not definitely known. We get the impression that the presence of much iron in the soil furthers the direct or indirect oxidation of the organic matter. If this be correct, then the calcareous black earth should have especially little iron. This is a point which should be investigated experimentally.

Of all the soil types upon the above-mentioned Miocene rocks, the last two mentioned are still the best, and the calcareous red earths gain that position because of their physically favorable nature. Even so, from an agricultural standpoint they have but a low value, and the true marl soils are certainly not much good; they are allowed to remain under cogon and spiny bamboo (see Fig. 204, page 584).

The allochthonous soils along the rivers are better, because there has also been washed onto and mixed with the marl material some volcanic lixivium. Hence the paddies (see Fig. 205, page 586) on these soils are of reasonably good quality, sometimes better, sometimes poorer, depending upon the components which predominate. In the north of Tegalwaroe region there are clays which have been deposited by the rivers. In these soils, besides "considerable quantities of hard, as well as soft, brown as well as black iron concretions and agglomerations of these concretions, there are also grayish to white lime concretions." The pH is high, to as much as 8.3 in the surface soil. The climate is quite a bit drier than in the south, at least there is a more definite dry season. It is notable that the rice grows well even with such a high pH; possibly it is because the irrigation water from the Tjitaroem River is so good. Elsewhere, as along the Tjibeët River are paddies with a pH of 4.4 to 5.4, which also give good harvests. It is obvious that rice can accommodate itself well to a wide pH range.

For further details the reader should consult the explanation accompanying sheet 30 of the Geological Survey of Java. Only this additional remark will be added here: Of the approximately 60,000 hectares comprising the "Tegalwaroe region" 23% are wild tropical forest, on the higher part of the Sanggaboewana mountain. Twenty per cent is paddy land in the low lands along the rivers. Then there is still 0.5% teak forest and 0.5% rubber and tea plantations, and the rest, 56% of the area, consists of useless cogonals, with here and there dwarf (parang) trees, and scattered clumps of bamboo (see Fig. 204, page 584). Such is the Miocene marl region. In the east monsoon the northern and principal portion is dry and then fire sweeps through the dry grass plains. Perhaps expert planting with teak would give some result, for as a whole this is an unproductive soil.

* * * * *

The high mountains, southwest of the region just now described and lying east of the road and railway connecting Poerwakarta and Bandoeng have an entirely different aspect. The three most important peaks of this volcanic complex are the Boerangrang, the Tangkoeban Prahoe and the Boekit Toenggoel, and the whole complex is younger than the previously mentioned Sanggaboewana and Parang Mts. That is to say, perhaps on the place where the Tangkoeban Prahoe and the other volcanoes now stand, in the first stage of their formation, volcanoes were already standing in that same Pliocene or Early Quaternary time. But those volcanoes, or their successors have then continued their volcanic activity much longer and more violently down to the most recent times. The Tangkoeban Prahoe is today still active, even within the past 35 years it has erupted ash.[82] Hence the whole landscape is more juvenile and

82. See: Ch. E. Stehn, Tangkoeban Prahoe, Fourth Pacific Science Congress (Java, 1929), Excursion guide B.3, pp. 15-16, with bibliography. N. J. M. Taverne, Vulkaanstudiën op Java, Diss. (Delft, 1926); and also in: Vulkanol. Mededeel. No. 7 (1926) p. 78, --with bibliography.

consequently richer in tuffs and ash as parent material, which in itself is still more basic. The following fact should not be overlooked, namely, that beside a considerable content of P, the rocks of the Tangkoeban Prahoe (see Table 115, page 560), have a K content of about 2% which is remarkably high. Perhaps this K has a favorable influence upon the potato cultivation in the environs of Lembang, for in this locality fertilization with potassium has no effect.[83] The detailed geological and petrographical study of this mountainous region by R. W. van Bemmelen,[84] followed by a short agrogeological description by J. Szemian shows very nicely what great difference in rocks,[85] in segregation forms, in weathering forms and in soil types are possible within the general, inclusive designation "andesite and basalt and their subaerial lixivia." It would be far beyond the scope of this book to consider van Bemmelen and Szemian's study as fully as it deserves. As to the rocks, we must be satisfied with an excerpt from van Bemmelen's "conclusion":

"The young eruption centers all belong to the same igneous province (pacific, intermediate lime-potash rocks: andesites and basalts). The phenomenon is remarkable, however, in that although all these centers come from the same general igneous source, the products of eruption of each volcano have had a tolerably distinct individual character. The differences are especially those due to the presence or absence of olivine and hornblende. Various things indicate that the "magma stoves" from which these young eruption cones have been built up were more or less independent.

The other volcanic complexes on Java, such as the great mass of mountains south and southeast of Bandoeng, the Diëng mountains, the Tengger, and the Idjen highlands, have not yet been studied and mapped in as great detail, but I believe that studies in those localities would also lead to similar conclusions. It would thus be interesting if with the help of chemical analyses, among other means, indications might be found as to whether or not the melting-in of older, quartz-rich, and even lime-rich rocks had taken place in certain "independent magma cells." And with suitable means it should be quite possible to distinguish soils derived from these different products of eruption from these several magma cells.

To the North from the above-mentioned volcanic complexes the lower mountainous land of Miocene marl ridges commences, which in the eastern part of the Tegalwaroe region occupies such a great area. The ejecta of the volcanoes flowed out toward the north in the form of mud flows, though these lahars were held up by the marl ridges referred to. But the rivers, flowing from the high mountain slopes in the south down toward the sea in the north, have cut through these obstructing ridges and have built out to the north a vast lowland. This lowland may be divided into a southern, more or less rolling, somewhat higher lowland, varying roughly between 25 to 100 m. elevation, and the northerly very low plain lying along the coast.

Related to this division into topographic zones we also find a zonation of soil types and land utilization. On the highest slopes, from 1,500 to 2,000 m. elevation, there is a brown andesitic lixivium with a considerable, brownish black, very humous surface horizon. Because of the need of protecting the water-shed this soil ought to be kept covered by forest.-- Between about 1,500 and about 500 m. is the zone of beautiful, humous surface soil underlain by a brown to brownish red lixivium, developed on and from the lahar material, as well as from the ash higher up, which has come especially from the Tangkoeban Prahoe. This is the zone in which, by preference, tea is planted. But in the highest gardens there is also much Cinchona, while some of the lowest portions, below 500 m., are planted to Hevea. Above 1,000 m.

83. See: de Verslagen Van Bemestingsproeven v/h Landb. Inst. v/h Alg. Proefst. v/d Ld. Buitenzorg (1929-1935).

84. R. W. van Bemmelen, Toel. Blad 36 der Geolog. Kaart v. Java (1934). With a korte, Agrogeölogische beschrijving by J. Szemian.

85. In this connection there is still lacking an accompanying series of analyses for all but the Tangkoeban Prahoe! See pp. 555-556 of this book.

a considerable portion of the soil is a pseudo-sand in structure, the very small aggregates of which make the soil loose and friable and also very erosive. Between Segalaherang and Kasomalang at not much more than 500 m. elevation, there is a plain which clearly demonstrates how true lava streams as well as mighty lahars have flowed down the slopes from the volcanic peaks. These flows, on the surface covered by much lava slag, have been blocked by higher ridges lying to the north, so that the lava spread out building up a sort of flat. Sheet 36 of the Geological Map of Java shows clearly that this lava is a basalt from a couple of craters of the Tangkoeban Prahoe, namely the Goenoeng Malang and the Goenoeng Nagrok.[86] Meanwhile, the slaggy upper surface to a moderate depth has been quite senily weathered and is a beautiful warm purplish brown lixivium with quite a good deal of humus. This region is now a plain occupied by excellent tea plantations. In so far as the lava stream referred-to flowed on further northwards in the direction of Soebang, on and along it lie beautiful paddies. But from the point where the lava ends, at about 200 m. elevation, to Soebang, at about 100 m. elevation, the highway runs through unutilized Miocene hilly land, such as is found especially east of the lava stream and north from Kasomalang.

Below the zone of tea cultivation there is thus between about 500 m. to about 100 m. elevation the generally less valuable marl zone. These lands might perhaps well be planted to teak, although in this continuously moist climate the timber will not be so hard nor so sound. Still lower, between 100 m. and 25 m. elevation is the zone in which much *Hevea* is planted, as well as kapok (Ceiba pentandra) and cassava (Manihot utilissima).

As the parent soil material is in part volcanic and in part has originated from the marls,[87] brought down by the rivers in former times, the soils are allochthonous and naturally not always homogeneous. It is generally accepted that the greater part of this material was deposited in the sea when the level was about 100 m. higher than at present, and as sediments was shifted eastward and westward by the sea currents. Both the mixing and the former bath in salt water are the reasons why this soil, at present weathered to red lixivium, exhibits a moderate but regular fertility and why the drier parts are planted to lucrative tree crops. In so far as it is irrigable with water from rivers coming out of the juvenile region of the higher volcanic slopes, this soil of course makes good paddies. Finally, there is the lowland which has been built up in the same way in more recent times. Since for the greater part it has been formed in the sea and along the sea, it has remained under subaqueous conditions and is thus still gray. Originally the whole was covered with swamp forest. But from the south outwards more and more of this low land is continually being used for paddy cultivation. Another large portion, which lies a little higher and was well drained, is at present extensively planted to sisal.

* * * * *

The further eastward one goes in the lowland, below an estimated elevation of about 100 m. above sea level, along the Tjipoenegara River and especially on the east side of this stream, the smaller becomes the influence of the volcanic hinterland to the south. In other words, especially toward the east, the greater proportion of the plain has been built up by weathering products from the Miocene marls. Just as the lower land was, for the greater part, formed out of quartz and clay, plus more or less lime in the beginning, especially the older, somewhat higher land has during later times been leached out in the course of the subaerial weathering and hence impoverished to fine sandy loams, reddish on the convex slopes, but gray in the concave portions. Rather poorish cogon grass and spiny bamboo grow on it. This terrain is amongst the very poorest of Java and, unless in the last few years it has been very much altered, out of this expanse one can today cut out a block of

86. Van Bemmelen, l. c., p. 42.

87. See Verbeek and Fennema, l. c., p. 471.

75,000 hectares where practically not a single mortal lives.[88] It is thus no wonder that the districts of Tomo (Tjongeang) and Losarang number but 130 and 132 persons per km.[2,89] as compared with the three adjacent good districts of Djatiwangi with 278, Djatibarang 345 and Sindang 328 (Indramajoe). All three of these districts benefit from the silt brought down by the Tjimanoek River. Conditions in other districts are similar--the Soebang district with soils formed from material with only a small portion of tuff constituents has 146 inhabitants per km.[2], being the most thinly inhabited of the former Pamanoekan and Tjiasem region. The southern, volcanic mountainous district Segalaherang has 191 persons, the Pagaden on a Quaternary plateau of volcanic rocks has 325, while the recent coastal districts Pamanoekan and Kandanghauer have but 163 and 160 inhabitants per km.[2].

Tengwal made an extensive study of the soils of the northern low coastal plain of West Java. A study which had a limited, preconceived purpose, namely, the classification of the soil types of this plain as to their suitability for growing sugar cane. Even so, this survey[90] was carried out in such a way that a number of data of general value have been obtained. Anyone who may be interested in this plain or in particular parts of it should consult the original publication. Below are only a few selected points which can be included within the compass of this book.

If the deposits of the large rivers, especially of the Tjitaroem, the Tjipoenegara and the Tjimanoek, since young Tertiary time, could be though of as non-existent, we would have a plain of about 20 to 100 m. elevation in the south and the true hign plain in the north, both for the greater part already formed in quite early Quarternary time, from weathering products of the young Tertiary rocks. East from the Tjipoenegara lay marls, poor in or free from volcanic admixtures. West from the Tjilamaja the marls contain more tuff constituents. This is noticeable in the higher, as well as in the lower plain. In the center, especially as to the former Pamanoekan and Tjiasem lands, on the higher plain that question is not easy to examine because those formations are now covered over with old Quaternary volcanic material. But in the lower plain, around Pamanoekan, there is still the same very heavy, old Quaternary clay as in Lower Krawang and in Lower Indramajoe, in so far as it has not there been covered over. This clay, dark gray in color, lying only a few meters above the sea is so heavy because of a considerable content of very fine quartz powder, which makes it actually an especially heavy clay loam. Upon drying out which takes place somewhat slowly, this soil cracks strongly into hard chunks. This soil is, above all, astonishingly poor in P: Table 124. This heavy clay

Table 124

	P_2O_5 in 0.001%	
	Hydrochloric acid soluble	Citric acid soluble
Indramajoe	33-10	3-0.3
Pamanoekan and Tjiasem lands	23- 8	2-0.4
Krawang	38- 6	5-1.0

contains iron concretions in the form of small round grains, hail ore or bean ore, but at the same time there are in many places also lime concretions in the form of irregular, small grains.

On the other hand in Recent time the rivers have spread out fresh deposits which are composed especially of volcanic material. They have done this through repeated shifting of their beds, which explains why elsewhere than along the present day channels of the rivers we find old banks of rivers (see Fig. 51, page 183). There are many cases where there are also former banks in the low, flat land to the left and the right from the streams. These "banks" lie somewhat higher than the plain, which during the greater part of the year lies under water, or at least as a result

88. See, for example, sheet 41-D of the Topographic map, scale 1:50,000.

89. Census 1930, I. Native population of West Java, Table 8.

90. T. A. Tengwal, Grondgesteldheid der kustvlakte van Indramajoe en Krawang, Meded. Proefst. Java-Suikerindustrie (1926), No. 10; Arch. S. Ind. Ned.-Indië (1926), pp. 287-335, with map.

of regulating and draining by man, is flooded. This is indicated by the gray, or at most brown-threaded gray color of amphibian land. The old stream banks were earlier exposed to subaerial weathering and so are now to be recognized as brown to red ridges in the low gray plain.

The Tjipoenegara, the smallest of the three rivers named above, has done the least for the rejuvenation of the soil. Its delta is also much smaller than those of the Tjimanoek and the Tjitaroem. The Tjimanoek, coming out of the heart of the Priangan is building a broad flat with predominantly volcanic silt and a little coarse sand extending easterly to beyond Karangampel, and westerly to near Eretan. In the south of this plain, close to Kandang Haoer, Losarang, Djatibarang, Bangadoewa and from there on further eastwards, at a very small but varying depth under that volcanic alluvium there is a pale yellow, fine sandy, older marl loam of early Quaternary nature. In the north the alluvium is thicker. But the soil type is still heavy, since there is quite a little marl silt (quartz powder) mixed through the soil. Likewise along the Tjitaroem there are alluvial silt deposits; in the terminology of this book those between Krawang and Rengasdenklok, however, consist of overflows. They are stream banks of moderately course to fine sandy colluvium; and they extend still further out to as far as the sea coast. But the true, clayey alluvium was carried out into the sea and accumulated on the sea bottom--and it continues to sink there. These youngest Tjitaroem deposits are indeed the most fertile lands of the entire north coast. That is, most fertile in terms of paddy produced because for other crops the soil is in general too heavy and as a rule is not sufficiently well aerated. Only a few crops, such as sisal and bamboo, after suitable drainage and some or considerable working of the soil can accomodate themselves to this type. Cocos are found only on the lightest, most sandy portions. Sugar cane can only be planted with hope of success on smaller portions of the plain, for example, on lands covered with some river silt along the Tjitaroem. In Cheribon[91] which is in the northern coastal portion of this region the sugar cane grows almost only on alluvial deposits from the Tjimanoek, which are preferably somewhat sandy, volcanic soils. From the agricultural point of view it is always very important--as for that matter indeed everywhere in the northern coastal plain--to see that the land has a slight slope, because good drainage is more important than is usually the case elsewhere.

* * * * *

Let us now turn to a consideration of <u>the Preanger (Priangan) proper</u>, made up of the administrative districts Soekaboemi, Tjiandjoer, Bandoeng, Garoet, Tasikmalaja and Tjiamis. The subdivisions of the region which we will use here will not, however, by any means parallel the administrative ones, for our units of subdivision must rather conform to the distribution of the soil types and their parent materials. As to this last we can, with Verbeek,[92] draw a line transversely across through the Preanger from the mouth of the Tjimandiri river to the mouth of the Tjitandoewi river, thus making two main divisions, a northern and a southern. South of this line are found only Tertiary rocks; a small spot in the most westerly corner is still older. On the contrary, to the north of this line the greater part is occupied by Quaternary to recent volcanic materials although here and there are little bits of Tertiary. This difference between the regions north and south from this dividing line is not only a difference in geologic age, but for a large part also a difference in kinds of rocks and consequently a difference in kinds of soils. This last expresses itself in differences in the density of the population of the different districts, especially if we take into consideration the percentages of those districts which are under cultivation.

91. Besides the paper by Tengwall already referred to, also see: F. Ledeboer, Versl. Veldpr. Proefst. Cheribon (1910-1911), Meded. Proefst. Java Suikerind. (1912), No. 25, Archief. J. S. Ind. (1912), pp. 757-875, where will be found a description of the kinds of soils, as well as maps.

92. Verbeek and Fennema, <u>l. c.</u>, p. 507.

In this connection let us look at the striking figures from the last census[93] for the districts lying within the region we are considering (see Table 125, page 593).

In a nutshell this table gives very well the principal features relating to the soil. At a glance we can see where the soil is used the most intensively and where the densest population can live upon it. The averages for the whole region are 215 inhabitants per km.^{2} and 41% of the area cultivated. All purely volcanic districts have a density of population greater than the average, all others a smaller one. The inhabitants have the most difficulty in maintaining themselves, that is, obtaining their food, in the marl and limestone regions along the southern coast, while it is the easiest for them in the purely volcanic regions. This is partly due to the infertility of the planted land, but also because the districts recognized as relatively infertile have so very little land which can be cultivated at all. Because of this, as well as because of the effect on the figures recorded of the areas of mountain forests and of the many European plantations, to go further into the distribution and density of the population would, for the purpose of this book, lead us too far afield.

* * * * *

In the southern part of the Priangan Regencies the rocks from which the soils have been derived are almost exclusively grouped by Verbeek[94] into the formations m_1, m_2 and m_3. As long as no more recent geological maps of this region exist, we must be content with this classification, and thus also with the closer differentiation of these formations, as Verbeek has given them:

m_1--"Breccias and conglomerates with fragments of andesite and of basalt, sometimes also of limestone, in a finer ground-mass which likewise consists of fragments of these eruptive rocks. Sometimes they are very hard."--It seems to me that these formations were probably originally lahars; thereafter they were cemented together by silicic acid (opal, chalcedony, quartz), though iron oxide could also have contributed to this result, as well as other secondary minerals.

"Claystones, gray and blue, likewise derived from weathered very fine andesite grains, with small kaolinite fragments."--I surmise that under this head there may be included illuvial horizons of weathering clay, such as described on pages 144, 145. In that case we would be dealing with a terrestrial formation and the lack of petrification is in no sense surprising.

"Light colored and even white sandstones and breccias with fragments of pumice stone" we need not consider again, for they were included in the discussion of the Bantam region, moreover there are only small occurrences of these rocks in the Priangan.

"Gray and green sandstones, consisting almost entirely of granular, finely broken up andesite; sometimes more or less calcareous (Foraminifera shells)." These I consider to have been originally marine deposits, banks along the coast, and that as a result of the salt water the darker minerals had been more or less serpentinized, giving the greenish color.

"Intercalated masses of eruptive rocks, especially pyroxene andesite, basalt, and quartz hornblende andesite (dacite)."

"Limestone, marls and clay slates" do not appear early in this m_1 formation and need not be considered here.

The climate of the southern Priangan, where the above-mentioned m_1 rocks are to be found, has continuously wet months (see the map, Fig. 6) with only a limited region in the west, facing the Wijnkoopsbaai and

93. Volkstelling (1930), I. Inh. Bev. van West-Java, Table 8; column 7 has been calculated in % of column 3.
94. Verbeek and Fennema, l. c., pp. 924-927.

Table 125

CULTIVATED LAND AND DENSITY OF POPULATION ON SOILS

DERIVED FROM VARIOUS KINDS OF ROCKS

District			Principal parent rocks	Cultivated land in % of the total area	Inhabitants per km.²
South Coast	Marls	Sindangbarang	Miocene marls m_2	8	42
		Pameungpeuk	" " "	14	55
		Boengboelan	" " " (+ breccias m_1)	17	57
		Djampang-koelon	Miocene: $m_1 + m_2 +$ limestone m_3	16	64
	Limestone	Tjidjoelang	" : limestone m_3	34	79
		Karangnoenggal	" : " m_3	30	88
		Tjikatomas	" : $m_3 + m_2$	37	92
		Palaboearratoe	" : m_1 (+ old volcanic)	21	93
		Djampang-tengah	" : $m_1 + m_2 + m_3$	22	101
Transition		Tjikadjang	m_1 (+ volcanic V)	28	127
		Soekanegara	$m_1 + m_2$ (+ volcanic V)	32	138
		Pangandaran	$m_1 + m_3$ + alluvium	43	141
		Taradjoe	$m_2 + m_1 + m_3$ + volcanic V	62	165
		Tjirandjang	mixed	56	177
		Soreang	m_1 + volcanic	30	179
		Bandjar	$(m_2 + m_1)$ + alluvium	51	183
		Tjikalong-koelon	m_1 + volcanic	42	183
		Tjikalong-wetan	" + "	47	198
		Tjililin	mixed	46	210
		Rantjah	m_2 + volcanic	78	228
Volcanic mountanous regions		Tjitjoeroeg	much mountain forest and plantations	41	258
		Bandjaran	" " " " "	43	277
		Patjet	" " " " "	52	292
		Pandjaloe	" " " " "	64	294
		Tjibadak	" " " " "	50	296
		Tjiparaj	" " " " "	49	303
		Singaparna	volcanic	64	317
		Manondjaja	" (+ some m_1 and m_2)	73	322
		Tjibeber	" + m_1	63	325
		Kawali	" + m_2	81	332
		Bajongbong	" , much mountain forest	55	345
		Bloeboer-limbangan	" + volcanic alluvium	72	361
		Tjitjalengka	" " "	72	383
		Tjiamis	"	80	400*
		Tjibatoe	" " " **	72	423
		Lembang	" , much mountain forest and plantations. **	55	441
		Leles	" + volcanic alluvium **	71	452
		Tjiandjoer	"	92	470*
		Tjiawi	" **	74	476
		Trogong	" + " " **	64	514
		Oedjongbroeng	" + " " **	79	529
		Garoet	" + " " **	75	530*
		Soekaboemi	"	70	545*
		Tjimahi	" + " " **	86	560*
		Tasikmalaja	" **	85	612*
		Bandoeng	" + " " **	76-88(?)	780*

*. According to the population and the area of the town of this name.

** . Have profitted by the fresh volcanic ash from the Galoenggoeng, Goentoer and the Tangkoeban Prahoe.

Photo by Bley

Fig. 206. Ravine in the Djampangs, West Java. Typical "bloekar" (second growth forest and shrubs) on kaiñgined slopes of m_1 mountain slopes, of old volcanic conglomerates. Soil a senile reddish brown to red lixivium.

the Zandbaai, which have a short weak dry season. As a consequence of the general, continuously leaching weathering, brown and red lixivia are the foremost soil types.

In this connection two points deserve attention. First, whether the rocks did or did not come in contact with sea water, and if so, for how long. Secondly, how old is the soil; in other words, in which weathering stage is it now.

In so far as these rocks had never had contact with the sea, the juvenile, brown to reddish brown kinds of soils developed from them are difficult to differentiate from similar kinds of soils developed from younger volcanic formations. But in part the soil types as soil are quite old and thus quite senile and at the same time are becoming more and more red. Vast regions which have been kaiñgined carry at present only miserable, low, secondary dwarf forest (bloekar) (see Fig. 206).

As the mechanical analyses show,[95] sand which could weather further is no longer present. But in Djampangkoelon one repeatedly comes upon more or less broken up thick layers of lateritic iron ore, to as much as 1 m. thick. These are the remains of the illuvial iron oxide layer, laterite, described on pages 144 ff. Entirely in agreement with this condition are the lamentations of planters who have gardens on m_1 lands and who complain of the occurrence of layers of white clay impentrable for water and also for roots. This is an illuvial clay horizon.[96]

In so far, however, as the rocks had indeed been in contact with the sea and the components had undergone their first alteration in the sea, the kinds of soil formed subaerially from them, even up to a considerable altitude above the sea, are still on the red than on the brown side. The strong brick red can then become even more a rose red. At the same time more clay minerals, kaolinite or

95. J. J. B. Deuss, Theegronden van Java en Sumatra, Meded. Proefst. Thee LXXXIX (1924),--Tables!

96. Compare: De Bergcultures 1, II (1927), pp. 1246-1249. On Flores (see pp. 240, 241, and Fig. 22, p. 149) are found identical broken masses of laterite and the clay horizon.

montmorillonite, crystallize out somewhat coarser, but yet still quite fine, so that in the frequency curve of the mechanical analysis the finest silt fraction is somewhat smaller, and there is somewhat more of the 2 or 3 coarser silt fractions (see tables of Deuss, above referred to).

As was described on page 145, under the white clay layer silicification has taken place. Consequently in old m_1 tracts, as in Djampangkoelon, and also elsewhere in Priangan, there are found many chalcedony nodules which show many colors and markings. At present these are being cut into beautiful semi-precious stones.

* * * * *

m_2--"Weak marls mostly of gray tints. Marl sandstones, likewise of only slight hardness. Lime marls, marl limestones, and limestones; harder than the former, and which may be called rocks."--One and all are marine rocks, which through leaching in the continuously wet climate lose their lime, leaving behind clay or loam. This soil can be gray or grayish, but also on convex terrains can be oxidized to more or less of a red, especially if a little fine volcanic ejecta has been included with the material. It is true that "eruptive masses of andesite and basalt occur at most but seldom" in this formation, nor are there many "volcanic conglomerate and breccia layers between the marls." But in places there is still enough of this material to somewhat color the pale clay or loam, and the iron hydroxide somewhat reduces the heaviness.

The coarse quartz grains, such as those which have been found in the m_2 rocks of the Tegalwaroe region and more still farther easterly, north from the Tampomas, and which give inducement to the forming of soils varying from lighter fine sandy loams to heavy loams, with a high silt content, do not occur again in the south of the Priangan. Apparently the parent land of this quartz-rich material, in the form of an extensive granite highland, lay in the direction of Borneo. The coarse quartz sand was carried out southwards as far as present day Java only in North Rembang, Soerabaja and Madoera, while the finer quartz sand came on farther south and farther west, though in the Miocene time not much of it got as far south as the present day southern Priangan. At most only very small grains of 5 to 20 mu.; a still smaller quantity as grains of 20 to 50 mu., and practically none of the coarser grains at all. The mineralogical analysis of the sand fractions resulting from the mechanical analyses illustrate this, although Deuss[97] makes no particular mention of the quartz grains. But in this connection we must bear in mind that in this paper Deuss was dealing exclusively with "tea soils," and that practically all these soils, also those which fall under Verbeek's m_2 tracts, are physicially better than the well known soils from elsewhere--the heavy, gray marl soils of the m_2 formation which are certainly avoided for tea cultivation.

m_3--"Lime marls and marl limestones of light gray tints, frequently in plates 2 to 6 cm. thick."--They have as a rule a higher lime content than the rocks of m_2, though of course this lime washes out. The nature of the admixture determines what the nature of the residual soil will be.

"Limestone, mostly with a little weathered andesitic gravel, sometimes however consisting entirely of calcium carbonate. The more marly "the lime" (thus richer in clay) "the less the hardness"; thus also the more rapidly it weathers.

The andesitic materials which are an admixture in these formations determine the nature of the soil. The cultivation of tea is possible in but a few places, especially where enough such andesitic soil remains over in the form of red lixivium. Since tea prefers an acidity of about 5 to 6, soils which still contain bits or

97. J. J. B. Deuss, Meded. Thee proefst. LXXXIX (1924), pp. 47-57. Only on pp. 42-44 was quartz even incidentally mentioned.

fragments of calcium carbonate, or where carbonate rocks lie close to the surface can at once be judged unsuitable for this crop.

In the localities with the Neogene rocks we have just mentioned, the valleys and ravines differ depending upon the nature of those rocks. In the predominately eruptive m_1 rocks, the valleys where the inhabitants cultivate paddy have relatively steep slopes and are moderately wide to narrow. The soil itself is not rich, but most of the water of the streams and larger rivers comes from the young volcanic hinterland in the north and northeast and brings fertility from that region with it. All the land which is irrigable is irrigated. These regions, by nature endowed with excessively much rain and (because of that) have a poor, but physically good soil for cultivation, form the classic example of the necessity of irrigation, not for the water, but for the plant food substances brought along with the water. Where it is possible water from the mountain rivers is used to irrigate the sloping valley sides, even though sometimes it is necessary to use long ditches to get the water onto such lands. The inhabitants also lay out paddies there. If that cannot be done, as on isolated hills, then the senile soil is not used at all or the villagers plant trees and bamboo on it, for these deep rooting slowly growing plants do quite well. In the north of the Djampangs one can observe various things which are favorable. In the west where there is no river in contact with high, young volcanic mountainous land, only few paddies are found and the ravines are also quite narrow. But in the east, where that contact does exist along the Tjitadjoer and the Tjiboeni Rivers, as well as along the upper course of the Tjisokan with the Tjiherang, there are extensive groups of paddies.

In so far as marls predominate in the m_2 rocks, the stream and river valleys have a broad V-cross section but the opportunity for paddies is small. There is but little flat land along the rivers and to lay out paddies on the slopes won't do, since these slide down bodily because the moist clay or loam of the dikes and terraces is too plastic to stand in place. On the topographic maps (scale of 1:50,000) the differences between the previously mentioned regions m_1 of favorable water supply and these m_2 regions are shown very clearly. In so far as hard marls and limestone predominate, the ravines are steep and cut down deeply (see Fig. 19, page 139) without flat land in the bottom, as is also usually the case in the m_3 limestone tracts. Consequently there is little opportunity for the laying out of paddies.

In the Djampangs the higher m_1 region, in so far as it is not too much cut up and too rough, has for the greater part been included in European plantations--the higher portion especially for tea, the lower mainly for Hevea.

As has already been stated, the senile soil is far from rich. In connection with this in the cultivation of tea great importance is attached to the preservation of the humous surface soil, and much care is expended to that end.[98] A young plantation thus profits from the plant food substances which the former forest trees had drawn up from great depths and have concentrated in the humous layer. Meanwhile the tea bushes can continue to grow and in the relatively loose soil develop an extensive network of roots to a considerable depth and in so doing can continue to do well. Nevertheless, it appears that fertilization with N (ammonium sulfate as well as organic manures) and P (especially basic slag) as a rule appears to be economically justified. All the soils referred to conform more or less closely to the characteristics of senile red lixivia--they have a very low content of easily soluble P, especially in the subsoil, while the content in the surface soil seldom exceeds 0.002-0.006% P_2O_5.[99] In most of the surface horizons of these soils the content of Ca soluble in HCl is not even 0.2%, though a small number have as much as 0.5-1%. Since the tea plantations generally lie between 400 m. and more than 1,000 m. elevation, the figures for the content of organic matter are still relatively high, namely about 6%, while there are some figures of more than 10%.

98. One may read about this in: Th. G. E. Hoedt, Overz. Werkz. Proefst. West-Java betr. theecult. (1934), in: De Bergcultures II (1935), p. 815 ff, in particular p. 819.

99. See: J. J. B. Deuss, Theegronden van Java en Sumatra, Meded. Proefst. Thee 89 (1924), p. 86 ff.

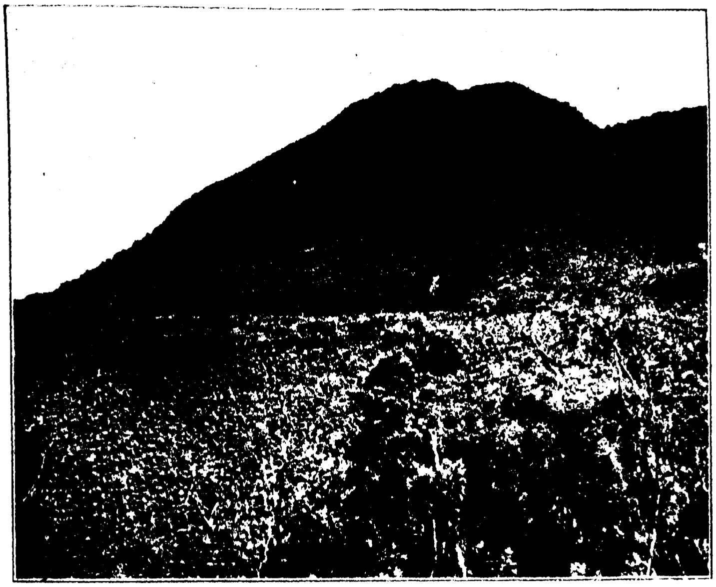


Photo by Bley

Fig. 207. Patoeha mountain, Priangan. The high tea garden extends up against the tropical high forest. Soil a beautiful humous brown lixivium, with mountain granulation. The plantation is terraced to prevent serious erosion.

But also others (presumably in eroded gardens) contain less than 2%. It is indeed a great pity that the tables of Deuss, from which these data have been taken, do not at the same time give the thickness of the horizons, espeically those of the above-mentioned soils. Also the tables would have been of very much greater value if they had included at least one profile from the surface downwards through all horizons, so that we would have had complete chemical analyses of typical profiles. It should also be mentioned that the figures of the matière noire and the N, and the considerations based upon them, are interesting. However, we cannot here consider these at length; the interested reader should read the original publications by Deuss.

* * * * *

At first glance the young volcanic mountains of the Priangan appear to be quite uniform as to nature and outward aspect, but upon closer consideration they are found to possess even more than the usual differences as regards the aspect of the soil types which are to be found there.

In general the country is high; especially the Goenoeng Kendeng range in the west, with the Patoeha, the Malabar group, the Kendeng complex, with which the Goentoer in the north and the Papandajan in the south can also be included along with the Tjikorai, and the Galoenggoeng. The whole region for a large part lies above 1,500 m.; some plantations even extend up higher than 2,000 m. while the highest mountain tops are still a couple of hundred meters higher (see Fig. 207 above). It is evident that differences in elevation, say from 500 to 2,500 m., must find expression in differences in the humus content of the surface soil.

Further, even though we can also lump together all rocks of these mountains under the broad terms of "andesites and basalt," yet there are differences. This is evident from sheet 36 (Bandoeng) of the

new Geological Map of Java. In fact it is even true of only one volcanic complex, the Tangkoeban Prahoe, on the map of which are given a full half dozen "eruption formations." Moreover two of these formations carry in their designation the qualification: "not further differentiated on the map." We can easily picture to ourselves what differences will be found in all the other above-mentioned volcanic complexes.

In the large Table 115, page 560 may be found a number of analyses of samples from Tangkoeban Prahoe, regarding which I have already called attention on page 588 to the relatively high K content. Samples from Mts. Boerangrang, Geontoer and Galoenggoeng show significantly lower P and K figures, but on the contrary markedly high Ca and Mg. As to P and K Mt. Papandajan has more nearly average amounts. A few samples have a relatively low FeO content, others much more than enough in order that all the Fe_2O_3 plus TiO_2 may be cemented to "ore," so that if weathered subaerially these rocks will give rise to dark brown soils. In short, detailed rock analyses can indicate important characteristics and peculiarities of the rocks and of those soils derived from them.

Moreover, differences in age, just as mentioned on sheet 36 will also play a significant role, perhaps even more as to problems of soil science than regarding purely geological problems. Isn't it true that for the geologist the greater interest might be as to whether a definite andesite occurrence is Pliocene, Old Quaternary, Young Quaternary, or Recent time, while for the soil scientist age is certainly of still more importance, because that is connected with whether the soil which is residual on the rock is senile, virile or juvenile?

Therefore it is here expressly stated that besides the Tangkoeban Prahoe, in historic times the Galoenggoeng, the Goentoer, and also the Papandajan have erupted and may break loose again any day. However, it may quite well be a century or longer before any one of them erupts again. On the other hand there are volcanoes, such as the Patoeha or the Tjikorai, which are permanently extinct. Consequently around the first named volcanoes are found the youngest products of eruption, fields of ash and lahars, and accompanying these volcanic products are the youngest and at the same time the most fertile soils. Consequently population is the densest on these formations (see Table 125, page 593).

* * * * *

With the exception of some plains which on all sides are shut in by higher mountains, and these will be spoken of farther on, the climate under which these volcanic products lie shows never a single continuously "dry month" (see the map Fig. 6). Consequently brown lixivium is the soil most likely to be expected on these basic volcanic rocks. The older and more senile the soil is, the redder the brown becomes. The higher the elevation and the more nearly untouched the soil has been under forest, or until recently has lain undistrubed under forest, the higher the humus content is. The more fresh ash the soil contains, the sandier it is. The higher above 800 to 1,000 m. a virile or senile soil type lies, the more clearly the mountain granulation is developed. These are indeed the foremost criteria according to which a Priangan mountain soil is classified. These criteria are also of practical importance, for example, for the <u>cultivation of Cinchona</u>.[100]

"From the numerous examples....it is now definitely known that the good soils can almost always be differentiated from the bad localities by a large number of very special characteristics, of which ....the following may be selected for special mention:--

(1) a higher content of sand;
(2) a higher humus content;
(3) a higher air content;
(4) a higher percentage of matière noire in the organic matter;
(5) a higher content of easily available P_2O_5;
(6) a higher figure for the degree of

100. P. Pzn. Spruit, Beoordeel. kinagronden n. gegev. verkr.d. anal. v/d. bodem, Bergcultures <u>4</u>, I (1930), p. 653. See also: Cinchona VI (1929), pp. 34-111.

saturation of the soil colloids; and (7) a higher content of lime."

Regarding (1). The higher content of sand[101] is a favorable factor, in the first place because it makes the soil looser and more friable. But then also in the second place because this sand is really "coarse ash" and therefore functions as a mineral reserve, with a favorable influence upon the factors mentioned under (5), (6), and (7). Part of the sand, however, and sometimes the major part of it is not unweathered sand at all, but on the contrary is "pseudo-sand" or "seemingly sand," which already previously (page 150) was pointed out to be grains mostly between the size limits of 100 and 500 mu,[102] but sometimes between wider limits. These "grains" are lightly cemented agglomerates of weathering minerals which behave in the soil as sand grains, and which in the mountain soils above 1,000 m. elevation do not easily break down.

Regarding (2) and (4). The rule that the higher the soil lies, the higher the humus content, may be approximately correct for undistrubed forest soils, yet in practice there sometimes occur many and sometimes wide divergencies, particularly where erosion has been marked. From the extensive series of data by Deuss[103] it will be noted that the content of organic matter varies between 28 and 2¼% and that the average is roughly 10%. Of that, about 2/5 is "matière noire," which in the most extreme cases may increase to about 2/3 rds, or may decrease to 1/8th. Thus there is a considerable variation in the amounts. The cultivation of tea can adapt itself quite easily to such varying conditions, but the requirements of Cinchona cultivation are very severe. Consequently the content of organic matter ought not to fall below 8% and that of matière noire not under 3½%. This may explain why, in growing Cinchona, so much use is made of green manures, particularly where the humus content is rather low. Also in the production of tea methods of cultivation are given much attention. But since tea is somewhat more modest in its demands than Cinchona, it can be planted on somewhat poorer soil and also under climatic conditions where some drought may occur earlier in the season. Therefore on account of the competition of the roots in these marginal cases green manuring for tea is not without danger, not only because of the relatively poor supply of plant food substances, but also because of limited soil moisture in a more or less dry season.

Regarding (3). For Cinchona the optimal pore space lies at about 27%. This is the same figure which is considered to be desirable for very good tea soils.[104] If the pore space falls to less than 20% the Cinchona quickly suffers. Tea, on the contrary, is somewhat less sensitive.

In comparison with many clay soils of the low lands, these mountain culture soils are indeed very "airy." This is due, on the one hand, to the high humus content, on the other to the "mountain granulation," which the "sand" content of the soil, even though it be only a pseudo-sand, so considerably increases.

As regards the water capacity of the soil, Spruit and Deuss have expressed it in this way.[105] The maximum water supply, which is the difference between the water content at the liquid limit and the hygroscopically bound moisture, should preferably be between 45 and 60. If the amount is lower than this, then these light soils dry out too rapidly and the plants suffer from a lack of water. If the value is higher than that then there is a lack of air.

Regarding (4). A few figures have been already mentioned relating to the matière noire. It is certainly the most active part of the organic matter and the

101. Spruit (Cinchona 6, 43) following the practice of the Soil Science Institute at Buitenzorg, calls sand the fractions from 2 mm.-0.25 mm.; clay that which is smaller than 2 mu, and the fractions from 250-2 mu the loam fractions. In Europe the fractions 250-20 mu are almost always called fine sand to dust sand or meal sand.

102. Ibid.

103. See tables in: Deuss, Theegronden v. Java enz., Meded. Proefst. Thee 89, pp. 59-81; and Spruit, l. c., p. 81-88.

104. Spruit, l. c., p. 58.

105. Spruit, l. c., p. 62.

higher its proportion is to the total organic matter, the better. It is the storehouse of the plant food substances such as N, P, K, Ca, etc., of former vegetation coming back onto and into the soil and concentrated in a place where it is easily available to the plant roots, so it can again enter the cycle. If the surface soil be eroded away, then since the essence of many generations of plant life is concentrated in this, as well as the active life of the microflora in the soil, the loss of this material is much more serious than the loss of the freshly fallen plant parts.

Regarding the significance of erosion, in this connection we may compare two sets of contrasting conditions, namely:

a. Acid, iron-poor volcanic ash, as contrasted with basic, iron-rich ash, and
b. Juvenile soil, in stages 1 to 2, as contrasted with senile soil, in stages 3 to 4.

We thus have four soil types as extremes, contrasted with each other, the differences of which are expressed most markedly in the subsoil. In order to eliminate further complications we will suppose that all of these soil types are at an elevation of 1,000 to 1,500 m., with a considerable humus layer, and under forest. Moreover, the ash is assumed to be of the same degree of sandiness; the slope of the land of all four being alike; and the rainfall equally abundant. Now what about erosion and its significance?

I. Acid, juvenile ash soils:--
Humous layer and subsoil both very porous and pervious. Except in the case of very heavy showers, the rain is absorbed and rapidly percolates down. The humus, especially the matière noire, is washed down into the soil. The humous layer grades gradually into the subsoil, down to a considerable depth, perhaps as much as 1 m. If surface erosion does not take place, the result is that the soil which remains behind is not "something entirely different," but through continual self-improvement can become like the earlier soil. The crops on it, for example tea, find adequate moisture and with the help of this moisture obtain adequate food materials. Erosion is moderately serious, but with the help of green manuring in continuing a modest supply of humus, it may be kept in control.

II. Basic, juvenile ash soils.--
In the main the same may be said of these soils. Only the weathering runs faster, the soil moisture is richer in bases and in P. Because of this the soil flora is more active--in a word the natural fertility is greater. Since the breaking down of the humus is more intensive, erosion under the conditions of cultivation is more serious. Therefore greater need for back sloping terraces (see Fig. 208, page 601) and more intensive green manuring.

III. Acid, senile ash soils:--
The iron-poor, pale yellow subsoil is more or less heavy and much more difficultly permeable. The lower limit of the mountain granulation lies farther upwards, to about 1,500 m. and higher. The humus surface layer is thinner and less mixed with inorganic soil constituents, thus richer in organic matter. The surface soil is more sharply differentiated from the subsoil and less than 1/3 m. thick, in extreme cases even less than 1 dm. In the humous layer the rain can still be taken up quite well, but only with much more difficulty is it passed on to the subsoil. The surface layer thus rapidly reaches saturation and supersaturation and then erodes easily. On open terrain or under a crop which does not cover the soil completely, erosion must lead to a bare subsoil, down into which little or no matière noire has been washed. In this extreme case erosion is simply fatal. In the long time during which the soil is becoming senile and the subsoil has gradually but certainly been leached out, the hydrogen clay has become more solid and thicker and since the subsoil had so little to offer--no food and even no water (because of the difficult permeability), the plant and tree roots have become concentrated more and more in the upper humous layer. Even green manures can no longer help this condition, for they themselves cannot grow. This is an extreme of infertility. Fortunately this type does not occur in the Priangan.

Fig. 208. The Government Quinine plantation, Tjinjirocan, Priangan. In the foreground backward sloping terraces, to prevent erosion. Beautiful loamy dark colored, humous volcanic mountain soil. In the distance, older cinchona plantings, and in the far distance tropical high forest.

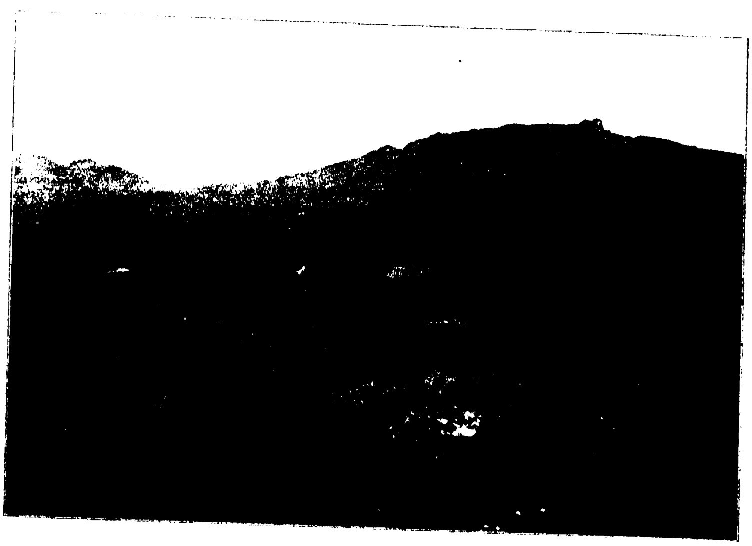


Photo by S. J. Wijmenga, Air Transport Sect. N. I. L.

Fig. 209. Plateau of Pengalengan, Priangan. In the center Mt. Windoe, to the right behind it Mt. Wajang, in the distance Malabar Mt. In the foreground are tea plantations. There are also cinchona plantations (darker in color back up against the tropical high forest). Ideal soil conditions for mountain plantation crops.

IV. Basic, senile ash soils.--As long as the soil still has a brown to reddish brown subsoil the latter is still reasonably permeable, because of the high content of iron hydroxide in it. The mountain granulation which increases the permeability, and also the washing down through the profile of the matière noire, begins already below 1,000 m. Though this subsoil is just as poor in plant food substances as the previous one, yet what is present is more easily available for the roots, which can penetrate down through the profile. They are also more available because of the accelerated water circulation. Erosion of the humous surface layer is also vigorous, in fact more serious than in the cases of groups II or I, but much less fatal than in the case of soil group III. Hence there is still much which can be done through careful timely covering of the soil, digging of pits, etc. to retrieve the losses and to prevent further damage.

If however, the subsoil has become so old that the iron hydroxides have lost their water and crystallize as goethite or hematite, and apart from that leaving behind a pale clay, which is colored red or rose color by the iron oxides just mentioned, then the permeability decreases and the conditions more nearly approach those described under III.

Now what we actually find are intermediate forms. Over the greater portion of its surface Sumatra has parent materials for soil formation which are more on the acid side, while Javanese parent materials are as a whole more basic. But on both sides the margin is quite wide, so that a large part of both groups have much in common. Moreover, in Sumatra almost all forest soils and certain agricultural soils lie between I and III, while in Java they are between II and IV. Thus it is a question as to how far the weathering has already progressed. And then one can say: in proportion to its senility. The more acid and poorer in iron the original rock was, and the greater the degree of senility of the soil, the greater the chance of failure under cultivation.

That this is especially true as to the good "water and air relationships" is clearly set out by Spruit.[106] The reader can find examples for comparison in Siantar (pages 487-490), Sumatra's West coast (pages 507-509) and among the tea soils and Cinchona soils of Java (Deuss, l. c. and Spruit, l. c.). The high plain of Pengalengan gives a beautiful picture of the last mentioned sort of soils (see Fig. 209, page 601).

Regarding (5), (6), and (7). Briefly, the magnitude of these values depends upon how juvenile the soil is. For Cinchona, Spruit showed that a high degree of saturation of the absorption complex, in particular with Ca and Mg, is accompanied by a higher production. The degree of acidity, or pH, "varies between 4.5 and 6.5, with a relatively wide optimum at about 5.6." As already mentioned tea can successfully endure a higher degree of acidity, thus lower pH values.

As to leaching, it has been mentioned repeatedly that of all the bases the Ca washes out the quickest. Na follows, then Mg and K. In this connection Spruit[107] has brought interesting facts to light. In good, not eroded soils covered by mountain forest, in the sorption complex the Ca content decreases with depth from the humous layer (about 0-25 cm.) toward the lower horizons (25-40 cm. and 40-60 cm.), while the Na content increases with depth. The explanation lies in selection by the vegetation, which takes up Ca the most rapidly and in the largest quantity, while for the most part it shuns Na. Hence the humous layer can indeed be richer in Ca. Potassium and Mg lie in between Na and Ca. If we now take into consideration the erosion of the uppermost portion of the soil, which even in tropical high forest is by no means negligible, then where the erosion is the most intense the new surface possesses not only less humus and matière noire but also less Ca and relatively more Na. The following instructive figures have been taken from a table by Spruit[108] (see Table 126, page 603):

106. Spruit, l. c., pp. 62-63.

107. P. Pzn. C. Spruit, Beschouw. omtrent bijzonderh. hooggelegen gronden (1000-1600 m.) i. verb. m. basen toestand. Versl. 12e Vergad. Vereen. Proefst. Pers. (1931), pp. 34-62. Also in Cinchona VII/VIII (1931), pp. 118-139.

108. Spruit, l. c., p. 47; Cinchona VII/VIII, p. 128.

Table 126

CONCENTRATION OF CALCIUM IN SURFACE SOILS

In a basin (with surface soil washed on)			On a ridge (somewhat eroded)		
	Surface	Subsoil		Surface	Subsoil
depth of sample	0-30	about 100 cm.	depth of sample	0-20	about 100 cm.
organic matter	9.25%	6.35%	organic matter	7.14%	3.90%
matière noire	1.35%	1.09%	matière noire	0.36%	0.31%
N	.633%	0.349%	N	.386%	0.236%
Degree of Saturation S/T	87%	86%	Degree of Saturation S/T	75%	87%
Ca	**11.6%**	**6.6%**	Ca	**2.3%**	**1.1%**
Mg	2.8%	3.4%	Mg	2.0%	2.2%
K	1.1%	0.7%	K	0.6%	0.9%
Na	**6.2%**	**14.7%**	Na	**16.6%**	**20.6%**

These figures speak for themselves. One can quite safely say that if still another sample were collected in the basin, for example 2/3 m. deeper than what now is called subsoil in the basin, one should have obtained figures closely similar to those of the subsoil on the ridge, as given in the right hand column.

The reader should here remember that above (page 151, 148) the possibility was mentioned that the mountain granulation, the formation of "pseudo-sand" might be due to very local, microlocal, pH's which should be lower than 4.5, so that there should be opportunity for solution of iron hydroxide, which then a little farther away, where the pH would again be higher, the iron would again precipitate. This process would occur especially in the strongly humous surface soil of the mountain tropical high forest, or in the layer lying just under it. Spruit[109] suggests, on the contrary, the idea that the pseudo-sand soils referred to in the beginning had formed deeper in the soil and that with respect to the sesquioxides (Fe_2O_3 and Al_2O_3) during a long time the "sandy" horizon has become more or less the illuvial horizon. From this it follows that such soils can possess relatively much iron which has cemented together the finer soil particles to pseudo-sand. But if this be accepted it is very difficult to explain why only pseudo-sand develops and there is no general cementing into a more or less harder or tuff layer. Neither conception makes it difficult to accept that as the parent material contains less iron, (as comes out above with the contrast of III and IV) there is less opportunity for the formation of pseudo-sand.

* * * * *

In the above I have dealt almost exclusively with tea and Cinchona which are shrub, or really small tree crops. Other crops are not grown so high in the mountains. Formerly in those locations much Arabica coffee was grown, but for coffee the climate was really too moist, so that when once the leaf disease got started this crop was wiped out with great rapidity. Where the elevation and at the same time the quality of the soil are not good enough for Cinchona and tea, most times the soil and climate are still very good for rubber. Consequently a considerable number of rubber plantations are to be found in the lower mountains and especially where the soil is not purely young volcanic, but has developed more or less from Miocene rocks. Only a few plantations have plantings of cocoa, citronella, or oil palms. Here and there the Forest Service uses kinds of trees which produce timber of economic value to successfully reforest lands which can maintain forests of native trees.

109. Spruit, Versl. V. V. P. P. 12e Verg. (1931), pp. 44-45; Cinchona VII/VIII, p. 126.

* * * * *

Rice is almost the only annual crop which is grown by the natives, and seeing that there is no lack of water in this rainy land, lowland rice is the principal sort. Paddy rice is grown not only on the large plains, but also on every flat or spot which can be made flat in the mountains, even up to elevations of more than 1,000 m.

It is obvious that the soils of all these plains differ notably among themselves. Moreover in one and the same plain the soil is by no means uniform. The main reasons for this are: (a) variations in the material from which the plains have been built up; (b) variations in the manner of deposit of the material; and (c) what has happened to it since.

(a) The plain of Garoet, for example, grading northwards by steps into the plain of Leles and Bloeboerlimbangan, is shut in on all sides by young volcanic mountainous land. Consequently nothing else but andesitic and basaltic parent material can come down into the plain, although in the course of time closer research will of course bring to light differences between the rocks of the surrounding volcanic formations. The still larger plain of Bandoeng is also surrounded by young volcanoes. Only in the south, according to Verbeek and Fennema, is there one small body of m_1 material which has no effect at all upon the nature of the plain, of no more effect than the m_1 ridges and little hills lying in the west along the lower edge. The plain of Batoedjadjar (see Fig. 210, page 605), on the contrary, is hemmed in by hills and low mountains designated as m_1 and m_2 on the map of Verbeek and Fennema. And something most probably still more important is that the streams which flow out of these hills come in part out of m_2 marl country and, as in the past, carry out from them fine quartz powder and lime. Also via the Tjisokan and its tributary river, the Tjidadap, the Tjihea plain continues to receive much marly detritus, although this will indeed not surpass the andesitic products coming in from the other sides.

Already I have touched upon the scarcity of analyses of the rocks of the Preanger, nor do there seem to be any analyses of water and/or of silt in the rivers which flow out into the above-mentioned plains.

(b) and (c). As to the manner of deposition, the plain of Bandoeng, in connection with that of Batoedjadjar has come into existence through the filling up of a large, irregularly shaped body of rolling lower land, lying between the Tangkoeban Prahoe complex in the north, the high volcanic land in the south, lower Miocene mountains in the west, and the Goenoeng-Tjalantjang complex in the east. During the process of filling, this plain most probably passed through an intermediate stage during which it was a lake. When in the older Young Quaternary[110] a great quantity of lahar material slumped down from the Tangkoeban Prahoe, this spread out into a half circle.[111] In the west and in the southwest this mud flow came up against a series of older volcanic ridges and hills which dammed the lahars, cut the plain off and made it a lake, which at its highest elevation reached 723 m. above sea level. Seeing that now in both plains there are points which are somewhat less than 660 m. elevation, at times and in places the depth of the water must have been more than 60 m. The Tjitaroem River, which once apparently flowed through the valley where the Tjimeta now flows, found first a threshold to the south of the Goenoeng Selatdjaoe and further west a way through the breccia and limestone ridge of Tagogapoe (see Fig. 211, page 605). In the course of time this river cut down its threshold and the contiguous channel, as a result of which both portions of the lake became dry. But before that stage was reached, all sorts of deposits could have accumulated in this lake, especially around the edges, so that today

110. See: Geol. Kaart v.-Java, blad 36 (Bandoeng) met: Toelichting van R. W. van Bemmelen en Agrogeol. Beschr. van J. Szemian (1934).

111. About the center of this half circle lies the city of Bandoeng; thus high and dry. The earlier Soekamiskin airdrome of Bandoeng, lying upon the heavy clay of the earlier lake, I condemned as being incapable of improvement. In the place of that there was recommended the present day site at Andir, on the half circle of lahar gravels mentioned above.

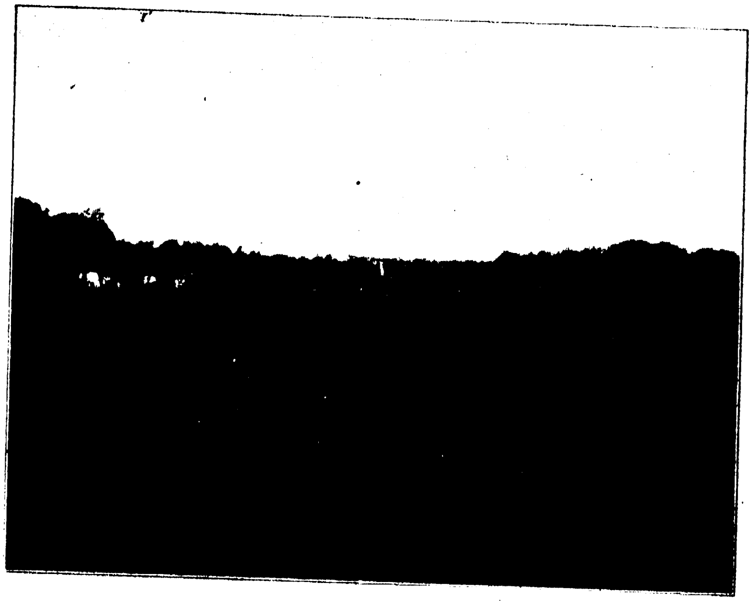


Photo by E. C. Jul. Mohr

Fig. 210. Plain of Padelarang-Batoedjadjar, in the Priangan. The soil from an intermixture of marl silt in volcanic silt is heavy and reddish black; formerly it was marshy. European cattle.

Fig. 211. Priangan. Tagog Apoe with limestone bluff at the left, which continues on into the right distance. At the left limestone is quarried for industrial use. Up on top the vegetation is not vigorous. This Tjimeta valley is fertile with volcanic deposits.

the plain is not entirely flat, for both from the north as well as from the south, particularly at the mouths of the mountain valleys, deposits are dimly discernable near the present-day course of the Tjitaroem. Between these very stumpy mountain debris-cones remain deeper spots which later became swamps, when the higher lake floor began to be exposed above the water level. Only very fine silt settled out in those swamps, so that these spots at present are covered by heavy, dark colored clay. Where the soil has been developed from the coarser deposits of the side rivers it is sandier and lighter; more like "colluvium."

During the time that the lake was still deep, layers of diatome shells were deposited in the quiet bays where little silt accumulated. Later these became mixed with lake silt (clay), and finally were pretty well covered over by that material. Near to Oedjongbroeng there is such a deposit where roofing tiles are successfully made and burned from a certain mixture of these deposits. Without doubt higher quality ceramic products can also be manufactured from these materials.[112]

The plain of Batoedjadjar (see Fig. 210, page 605) is not by a good deal so flat as that of Bandoeng. It is more rolling, not to say rugged. There are also a number of low spots in it where swamps have been. These now however, have disappeared.[113] Not many lahars flowed directly into this valley, but in it a great deal of sediment accumulated, also much marl silt rich in lime. The Tjihea plain not so long ago was very swampy, but it has now been improved, having been drained, and the sanitation improved. It lies much lower than the plains previously mentioned, namely at about 260 m. above the sea. Also the Miocene marls, besides andesitic breccias and conglomerates, have supplied much material for the building up of this plain.

Of these "plains" the most easterly from Bandoeng is really no plain at all, but a sloping lahar debris field stretching irregularly from the south-southwest and the west toward the east and north-northeast. In the south, at Bajongbong the elevation is still about 950 m. at Garoet and Trogong about 720 m. at Leles about 700 m. at Tjibatoe about 650 m. and at Bloeboerlimbangan only 550 m. The Tjimanoek river flows just east of the last-mentioned place and in places has cut down to 500 m. and even lower. It is indeed marvelous how on this mighy lahar field every opportunity has been taken to lay out paddies up out of which stick countless large stones which indicate how juvenile the entire landscape still is. The Goentoer has apparently been the last to contribute to this formation. For example, between Leles and Tjibatoe the road crosses the head of a lahar which is still sandy and gravelly because the andesitic fragments are all fresh. In the south, at Garoet, the soil is somewhat older and more brown to brownish red. Along the banks of the Tjimanoek which are steep and cut down deep may be seen the thick layers of light yellowish gray juvenile lahar gravel, on the top of which lies a stronger brown colored surface soil.

Paddy fields are everywhere (see Fig. 212); but not all are equally fertile. Because of the enormous variability of the soils it is impracticable to give figures to express the "fertility" of the Priangan paddies. It is true that the "fertility" always refers to the yield of rice, but in a variety experiment in the Tjiamis district in a single test 10 different kinds of rice varied in yield from 12.4 to 46.9 quintals per hectare, and upon the repetition of a second experiment with 5 of the same varieties, from 47.8 to 77.5 qu./ha., the same 5 which in the first experiment had given 33.4 to 38. qu./ha. These differences are apparently not to be ascribed to varietal differences alone. For it also happens that a large number of diseases and pests attack the Priangan paddy so that the true fertility becomes masked. In many places "mentek," may be found, a disease, the true cause of which has not yet been definitely determined. While the

112. Compare: E. C. J. Mohr, Grondenderzoek en Keramiek, Meded. Lab. Agrogeol. en Grondond. No. 5 (1920), pp. 21-23 and Table VIII.

113. But the diatome shells can still be found in the soil, just as in the black or brownish black clay at Tjimahi, at Nagrek, and even at Plered.

Photo by Aerial photo section N. I. L.

Fig. 212. Mt. Gedeh, Priangan, viewed from the southwest. Above at the left, the caldera. Further to the right, Mandelawangi, the Pangeranggo peak.--The steep ravines and the ridges above are covered by tropical high forest (forest reserve). Elsewhere all paddies and villages.

older theory that it was a parasitic disease has now pretty generally been given up, authorities differ as to whether it is to be described to unfavorable physical factors in the soil, or to a lack of certain plant food substances (K) or unfavorable ratios between them. However this may be, in the Priangan much mentek occurs and a search is still being made for the real cause.[114] Then the number of crop pests is legion: white and yellow borers, hemipterons (walang sangit and others), rats, and birds. Almost no harvesting experiment is ever carried out in which there is certainty of freedom from diseases or pests. To what extent the characteristics of the soil and the climate are fundamental factors in the occurrence of the diseases and plagues we do not yet know. Yet they do belong to the fertility conception in general. Finally it must also be mentioned that even in this land well supplied with water there is sometimes a lack of water in the paddies.

In spite of all these factors which depress the yield, we can conclude[115] that with adequate irrigation water and a minimum of diseases and pests, but without fertilization, the paddies in the east, in Tasikmalaja, Tjiawi and Tjiamis produce approximately 25-40 quintals paddy per hectare, in the plain of Garoet 30-50 qu./ha., in the Bandoeng Plain 30-50 qu./ha. and more; and in the Tjihea plain 20-70 qu./ha. Because of the diseases and pests mentioned, over large areas the yields often fall to half the above or less. For example, in 1927 the regency of Tasikmalaja produced but 19 qu./ha. and Tjiamis only 14 qu./ha.

114. See L. W. Kuilman, Onderz. mentekziekte v/d rijstplant, Landbouw 11 (1935), pp. 77-113; and: Symtomen v/d mentekz. v/d rijstplant, Landbouw 12, (1936), pp. 225-245.

115. Compare: Jaarverslagen Lb. voorl. dienst--to 1925; idem, Afd Landbouw (1926-1929); idem, van Bemest. proeven v/h Landb. Instituut v. Alg. Proefst. Landb. (1930-1935).

Moreover from a number of experiments it appears that a deficiency of P is generally prevalent. In this connection compare the analyses of the rocks of the Goentoer and the Galoenggoeng with, for example, those of the Slamat. Consequently an application of 87 kg. double superphosphate (DSP) (sometimes but half that much, or sometimes 131 kg. or even 174 kg.) per hectare almost certainly works wonders. Increases in the yield of 5 qu./ha. are weel nigh the minimum, 10 qu./ha. an average, while increases of 20 qu./ha. are by no means exceptional. Especially in the Tjihea plain there is a "heavy black marl clay" which when fertilized in this way, the usual yields of about 20 qu./ha. are increased to 45 to 50 qu./ha. and more. There are also indications that fertilizing with DSP in general hastens the ripening of the crop 1 or 2, or sometimes even 3 weeks, consequently appreciably decreasing the damage caused by animal pests.

Except in the Tjihea plain there is, besides the deficiency in P, also in many places a lack of nitrogen and even here and there a lack of K. It thus appears that the Priangan paddies have a much greater potential productive capacity than their present day yields indicate, so that with appropriate irrigation, correct fertilization and careful combatting of diseases and pests, without any doubt in the future the production can still be considerably raised. The exemplary handling of the Tjihea plain is proof of this. Relative to this the Agricultural Extension Service of West Java gave an excellent review,[116] which the interested reader is urged to consult.

* * * * *

This same type of "heavy, black marl clay" soil also occurs here and there in the plains of Batoedjadjar and of Bandoeng, but not at all in the Garoet plain. In this last-mentioned area calcium carbonate is never found in the subsoil, while in the Tjihea plain, however, at about 1 m. depth there is an "andesitic fine gravel cemented by lime."[117] Although as was to be expected (see Table 127, page 609), the plains referred to show generally relatively low rainfall figures and all have a clear to very marked dry season yet, in so far as I know, calcium carbonate concretions in masses [118] have been found only in, or more correctly under, the Tjihea plain, in spite of the fact that it has the least pronounced dry season. Loose lime concretions or nodules occur here and there in the subsoils of the plain of Bandoeng.[119] The explanation of this phenomenon may perhaps be found in the building up of the Tjihea plain on a basement of basaltic lahars from the Gedeh, Miocene marls coming down via the rivers may have become mixed with much relatively $CaCO_3$-rich sediment. The plains of Bandoeng and Garoet have been built up entirely of volcanic products, gravel, sand, and silt, and the rivers which today bring on sediment-laden water also come out of entirely volcanic regions. As to these volcanic rocks it can be said with certainty that they do not contain calcium carbonate and the water coming from the volcanoes must thus bring on less lime. Consequently there can be but scanty formation of lime concretions in the central part of the Bandoeng plain. But the plain of Garoet and Limbangan has apparently been formed too recently[120] for there to have been time for formation of $CaCO_3$ concretions and for the formation of the heavy black clay. In these plains the weathering conditions may be considered as about on the boundary between amphibian and subaqueous on the one side, and between intermittent leaching and alternating weathering on the

116. A. C. Koorenhof, A. H. A. Corts, and L. J. Vroon, De Tjihea-vlakte enz., Landbouw 9 (1934), 441-489. In this are extracts from a report relating to the soil mapping by H. J. te Riele (1933) and important data relating to analyses of the soils, the irrigation water and silt by J. Th. White (1923). Neither of these last two mentioned reports has been published.

117. See: Landbouw 9 (1934), 443.

118. See: Landbouw 9 (1934), 443.

119. See: J. Szemian, Toel. bij blad 36 der Geol. Kaart van Java (1934), p. 90.

120. See: Verbeek and Fennema, l. c., p. 757.

Table 127

DISTRIBUTION OF THE RAINFALL DURING THE YEAR ON THE HIGH PLAINS OF WEST JAVA

	Locations	Elevation above sea level	Number of years of observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year
Tjihea Plain	Tjirandjang........	263	21	208	220	279	242	175	90	60	105	117	219	288	249	2251
	Boemiajoe..........	292	10	291	283	364	325	211	79	73	63	86	253	356	314	2768
	Pasirgombong.......	295	21	223	249	239	254	186	95	53	70	98	219	266	246	2199
	Tjibarengkok.......	350	21	272	271	287	310	226	125	82	89	123	234	302	273	2594
Padelarang Plain	Tjiboeroej.........	740	25	184	185	195	166	98	49	41	39	55	136	177	212	1534
	Padelarang.........	685	32	213	199	222	197	113	51	39	38	71	161	202	213	1719
	Batoedjadjar.......	660	18	195	188	240	227	129	65	42	45	83	168	245	207	1835
	Sindangkerta.......	730	12	242	198	289	262	166	85	50	67	91	228	303	231	2232
Bandoeng Plain	Tjimahi............	787	33	182	181	194	187	133	60	49	49	90	176	214	210	1724
	Bandoeng...........	715	52	199	181	145	231	140	89	62	58	84	171	238	235	1934
	Djatinanggor.......	760	52	262	241	273	216	136	92	61	35	57	128	222	295	2018
	Madjalaja..........	670	28	292	307	343	300	203	101	72	53	94	191	297	305	2568
	Tjiparaj...........	673	29	265	245	289	264	161	80	60	37	91	180	266	282	2220
	Tjangkring.........	670	27	230	217	275	233	174	61	68	50	64	177	251	240	2040
	Bandjaran..........	675	12	236	177	299	268	182	87	60	77	61	209	287	255	2198
	Soreang............	750	12	226	187	258	242	166	75	40	60	83	205	269	234	2066
	Bloeboerlimbungan..	540	10	286	309	322	181	92	57	25	11	13	99	145	266	1806
	Malangbong.........	619	18	383	359	441	371	270	108	41	36	51	139	291	412	2902
	Tjibatoe...........	612	16	230	211	255	169	124	50	22	22	34	104	165	229	1614
	Garoet.............	710	28	260	234	268	211	151	95	62	48	65	133	210	271	2028
	Trogong............	735	10	277	235	303	189	131	66	42	14	17	91	189	334	1887
	Leles..............	710	10	322	260	362	236	166	55	46	10	10	83	193	363	2108

other side.[121] From this it is easy to understand that the color of the soil is black and on the somewhat higher lying spots dark blackish brown, with reddish brown iron oxide streaks and veins. Where the soil is used permanently as paddy land the color is continuously black to gray; when dried out and granulated, however, it always inclines somewhat toward a brownish color.

* * * * *

Where the railway line runs through the eastern Priangan one is astonished at the great number of cocos along the line between Tjiawi (500 m. elevation), Tasikmalaja (350 m.), Manondjaja (290 m.) and Bandjar (40 m.). And at the same time one is surprised at the generally bright red lixivium soil on which they stand. Ordinarily large groves of cocos do not grow at such elevations; they are found more usually between sea level and 25 m. Thus there must indeed be some special reason for cocos growing here. Although it is true that off and on Goenoeng Galoenggoeng volcano has spread a little rejuvenating ash over them, these red soils are already relatively senile. Where these soils can be irrigated with fair to good irrigation water, this is done although the yields are also lower than on the soils more to the west. On page 607 paddy cultivation has already been touched upon. The cocos stand on the unirrigated and unirrigable lands. In this connection the reader may recall that earlier[122] in this book we have quoted Tammes who maintains that a continuous and adequate water supply is the most important requisite for the coco palm. If we but glance at the rainfall figures (see Table 128, page 610) we will realize that in these localities there is no lack of water nor a long continued dry season, except in the two extreme cases of Tjiawi, lying in an enclosed depression, and Bandjar which is very low down. Mangoenredja and Tasikmalaja have not a single month's rainfall with an average under 150 mm. It even rains throughout the entire east monsoon, because the east-southeast wind is

121. Compare Table 54, p. 162.

122. Compare p. 512 of this book.

Table 128

DISTRIBUTION OF THE RAINFALL DURING THE YEAR IN THE COCO REGION OF EAST PRIANGAN, JAVA

Place	Elevation above sea level	Number of years of observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Rainfall in mm. per year	Arid (dry) months	Humid (wet) months
Tjiawi.......	500	12	387	303	374	262	192	95	61	50	43	146	272	346	2533	2	8
Radjapolah...	455	12	436	334	418	290	220	119	99	63	71	240	422	458	3169	0	9
Mangoenredja.	405	41	312	335	330	336	271	209	155	161	173	328	357	363	3331	0	12
Tasikmalaja..	350	44	361	376	459	334	277	201	168	154	178	340	389	392	3630	0	12
Manondjaja...	290	52	363	359	374	269	227	192	143	106	124	263	317	376	3113	0	12
Tjiamis......	228	19	392	358	352	278	183	129	94	75	92	238	292	397	2879	0	9
Boemiseuri...	300	18	567	484	474	367	263	148	84	91	129	263	349	523	3743	0	10
Kalangsari...	200	16	607	525	573	419	283	193	128	109	140	308	423	649	4357	0	12
Bandjar......	40	24	308	281	331	239	190	116	74	74	75	218	262	301	2468	0	9

forced upward by the mountains, the regular rains are thus due to the cooling brought about by the rising air currents. Because of the strong continuous wind which prevails here it would be worth while to determine the composition of the water which falls in these rains. It does not seem at all improbable to me that sea spray has been carried inland by the wind and is an important factor in the productivity of the coco palms of this region.[123]

* * * * *

Off to the northeast of the mountainous Priangan region, but connected with it by a series of a few older and somewhat lower volcanoes and groups of volcanoes, of which the Goenoeng Simpai with the G. Tjalantjang, and also the G. Tjakraboewana and the G. Sawal are the foremost, stands the Tjerimai, an otherwise quite isolated volcano of more than 3,000 m. elevation. Because of these relationships this mountain is a very effective wind and rain catcher, and so of the highest importance for the low land of Cheribon because of the beautiful and abundant supply of irrigation water which runs off from this mountain. The following rainfall data (see Table 129, page 611) demonstrate this very well.

It is evident that there is a regular increase of rainfall with the elevation, and this is maintained at all stations above 100 m. If the northern low plain has a marked, long continuing dry season, the farther south one goes the less pronounced this is. But even up to great altitudes this continues to persist and at the peak (3,078 m. elevation) there is considerably less rain than at about 1,000 m. elevation.[124] It is thus the zone between 200 m. and 1,500 m., which has the so-called rainfall surplus above the evaporation, and it is especially from this zone that the rivers are fed. There were previously already low mountains of Miocene rocks, especially marls, where the Tjerimai has now built itself up. A large part of these marls has now been covered over, but at a number of places, for example, between Kadipaten, Darmaradja, Telaga and Madja, and in the east at Mandirantjang, Tjilimoes, and further on, little bits of that marl land stick out between mud flows from the Tjerimai. Except for these pre-volcanic rocks the water flowing off toward the plain of Cheribon, both toward the north as well as toward the east, should be unconditionally good both from the standpoint of the formation of alluvium in the past as well as of irrigation at the present time. However, these marls greatly influence the conditions because of the enrormous quantities of silt which have come from them and which make the soils of the plains physically heavy and "sticky," while chemically these silts impoverish rather than enrich the soils, or at least they reduce the productivity.

The marl land which has been mentioned as lying west from Madja is an excellent but horrible example of soil

123. Compare p. 513 of this book.

124. See for example the rainfall data for 1929.

Table 129

DISTRIBUTION OF THE RAINFALL DURING THE YEAR AT DIFFERENT ELEVATIONS ON THE TJERIMAI VOLCANO

Place	Elevation above sea level*	Number of years of observations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average annual rainfall in mm.	Rainy days per year	Rainy days in the 3 driest months	Dry months	Wet months
Rambattan (Sindang)..	3	41	257	256	151	128	100	73	50	21	29	56	127	178	1421	82	7	4	7
Bangadoea............	13	52	318	269	244	163	111	78	48	26	32	65	169	324	1847	98	7	3	7
Djatitoedjoeh........	19	31	381	283	325	168	122	71	40	23	56	107	227	331	2134	106	7	3	8
Kadipaten............	38	29	461	402	405	302	170	79	58	32	64	137	270	367	2746	128	9	2	8
Madjalengka..........	130	29	551	488	462	321	206	116	69	35	83	154	288	439	3211	158	12	1	9
Madja................	556	30	719	674	563	372	250	124	79	38	73	204	363	579	4038	179	14	1	9
Sadarèhèh............	1110	41	963	944	705	429	271	151	86	60	78	163	398	694	4947	189	15	0	9

*The figures of elevation, as given in Vol. 24 of the Kon. Magn. Meteor. Observator., have in places been corrected with the aid of the newer maps of the Topographical Survey.

destruction through deforestation, pasturing of cattle, and fire, followed by heavy erosion. The series of photos (Figs. 213-217, pages 612-615) reproduced through the courtesy of the Forest Culture Experiment Station, gives a good idea of the conditions.

* * * * *

This is perhaps a good place to impress strongly upon the reader that chemical analyses of different soil types, all carried out in precisely the same manner, for example by digesting with HCl of definite strength and then determining in the extract the amounts of such constituents as K, Ca, Mg, and P down to a thousandth of a percent, can never give comparable figures unless one keeps strictly within one soil type, for only then can profitable comparisons be made. The purpose of such chemical determinations and comparisons is practically always to learn something about the productivity of the soil and as a rule to be able to speak about it with respect to some certain crop as, for example, rice or sugar cane. But then the quantity of any given plant food substance such as K extracted by HCl from completely disintegrated and dispersed soil is unimportant in comparison with the quantity of K which is available for the plants or may become so in the soil in one growing season. It is obvious these elements must be present in the soil, but what is more important the roots and the food substances must be able to find each other. Now in a stiff marl soil the roots grow slowly and with extreme difficulty as compared with their behavior in a loose, fine sandy ash soil or a reddish brown, light lixivium. On the other hand the water movement in the heavy soil first mentioned is extremely slow or there may even be no water movement at all. If the root tips have sucked dry their surroundings, even though it be only once, then there is not much left to take up, even though there are moisture and plant food present but a few cm. or even only a few mm. from where the roots are. The means of delivery to the roots is lacking. For such heavy, stiff soils, the principal thing agriculturally speaking is to facilitate the delivery of the nutrient substances to enable the roots to grow more easily and more rapidly. It would be fine if through some kind of soil amelioration (liming, green manuring, farmyard manure) these can be facilitated, provided that one does not make the mistake of supposing that in the first place this manuring makes up successfully for a deficit of certain plant food substances. In these extremely heavy loams and clay lands as a rule the most important effect of amendments is facilitating water movement, and so continuing the supply of whatever the plant roots take up. As to making up a lack of plant food substances, the increased water movement enables the plant food substances already present in the soil to be brought more easily within the reach of the roots.

Any one who has had experience in handling the many kinds of alluvium of Java has often learned this from experience.

Photo by the Forest Experiment Station

Fig. 215. Sindangpalai ridge near Madja, Cheribon. In the distance Mt. Tjerimai. After clearing the forest, cattle are pastured on the marl ridge, so that the soil is disintegrated and ruined. Heavy rains cut gullies.

The beautiful, detailed descriptions of the soil types of the low land of Cheribon by Ledeboer[125] also testify to this. In this study, apart from some more or less residual soils (his "laterite" is really red lixivium, and his "andir land" is a still juvenile, brownish gray lixivium. Both have originated from andesitic ejecta), especially heavy to very heavy kinds of clay have been differentiated. Judging from their position and their description, as well as from the results of the mechanical analyses, these soils must be definitely considered as river deposits, thus as allochthonous soil formations. Apart from them there are the so-called "Paninghiran" lands in the west along the Tjiloetoeng and the Tjideres Rivers, as well as some more northerly-lying silted up soils along the Tjimanoek, which are the least heavy. On the other hand the "Tjimanis" lands lying to the east are as a rule, much heavier. But there are variations which are to be ascribed to the source of the soil material. If this material has come especially from the marl terrains which, although according to area are also smaller, yet erode much more intensively than the volcanic formations (see Figs. 215, 216), then the resulting soil is intractably heavy. While if the material has come from the Tjerimai volcano, then the physical condition especially of the material which has flowed out over the surface is much better, since there is then also sand mixed with the soil. In short, as the discussion by Ledeboer shows, it is evident that the origin of the soil material is the principal factor determining the physical condition of the soil and consequently its value. For that matter, we have already seen the same relationships in the description of the entire north plain of West Java (see pages

125. F. Lederboer, Versl. Veldproeven (1910-1911), Meded. Proefst. J. Suikerind. No. 25 (1912), Arch. Java-Suikerind. (1912), pp. 757-875 with many appendices and 2 maps.

Photo by the Forest Experiment Station

Fig. 214. Sindangpalai ridge near Madja, Cheribon. The second stage, following that shown in Fig. 213. The sod is broken; the small erosion gullies unite to form larger ones, which become ravines. The entire surface gradually slides downward, helped by the carabao (water buffalo, note one on the sky line). Attempts to lay out paddies were a failure so they had to be abandoned.

Photo by the Forest Experiment Station

Fig. 215. Sindangpalai ridge near Madja, Cheribon. The third stage, following that shown in Fig. 214. A bare and abandoned marl landscape, the tragic result of deforestation and overgrazing. Incredibly heavy erosion of which a detail is shown by Fig. 216.

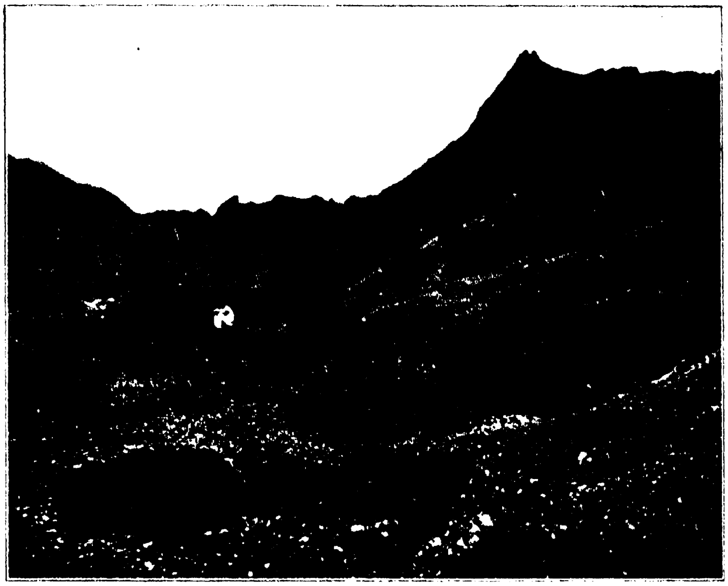


Photo by the Forest Experiment Station

Fig. 216. Detail of the landscape of the Sindangpalai ridge near Madja, Cheribon (cf. Fig. 215), in the drainage basin of the upper course of the Tjikeroeh river. Annually this terrain loses one meter elevation through caving off, sliding down and washing off!

589-591). Next to the source of the soil material, the second most important factor is the water supply. How very true this is appears from the following:

North from the Tjerimai lie the Kromong mountains, a separate, older, volcanic complex of a couple of hundred meters elevation. The rivers coming from the Tjirimai run either to the east or to the west around these mountains; thus much water flows by that way. Northeast from the Tjerimai, and south from Cheribon, there is a somewhat higher volcanic region, the small Cheribon basaltic volcano which did not develop further. These immature volcanic elevations also hinder the natural drainage and have, for example, deflected the Tjimanis, compelling this river to flow around in a loop. Resident Hiljé[126] wrote as follows in 1930 of "the district of Cheribon which is not well supplied with water" (see Figs. 218 and 219), while Ploembon, west from there, and Sindanglaoet, to eastwards, have more water available. In this connection, in the districts of Tjiledoek and Sindanglaoet, although the soil (with much marl material) is less good, yet in the east monsoon about a quarter of the paddy lands, which at that time are not planted to paddy are planted to another crop. While in the district of Cheribon, on the contrary, but 1/10 of the area is so planted, and what is, lies exclusively along the irrigation ditches. In Ploembon the raising of onions is also "of significance." These data from the Civil administration make clear why the density of the population in 1930, relating to the same year as that of the Memorandum of the Resident mentioned above, were as follows:

District	Inhabitants per $km.^2$
Palimanan (with the Kromong Mts.)	641
Ploembon	1,075
Cheribon (exclusive of the municipality)	625
Sindanglaoet	591

126. C. J. A. L. T. Hiljé, Mem. Overg. Res. Cheribon (Juni 1930), p. 67-75.

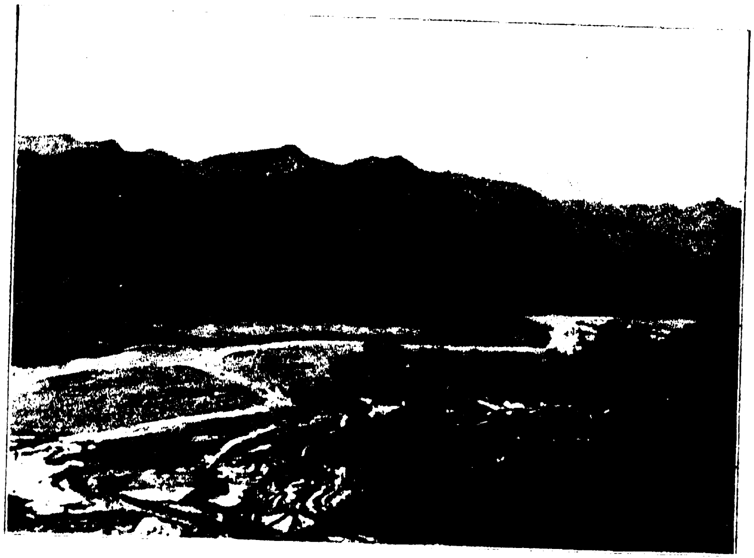


Photo by the Forest Experiment Station

Fig. 217. View of the broad bed of the Tjisoelooheun River, a tributary only 10 kms. long, of the Tjiloetoeng, Cheribon. After a heavy rain the sludge-like water flows 1 meter deep over the entire width of the bed. The entire surrounding marl region is deforested.

These data indicate that both the soil and the water supply are of great importance. It is also notable that in general all these figures run so much higher than those of West Java; while this heavy clay may be difficult to work, yet its fertility makes the effort worth while!

* * * * *

In the paper by Ledeboer one of the most important chapters is certainly that about the "<u>rantja minjak</u>" soil. This is the soil type which in the first part of this book[127] I have called "black earth," and characterized by its formation from mostly fine granular, fine sandy, to fine loamy parent material. It is formed under a climate with a marked dry season, which brings about alternating weathering. Seeing that here in Cheribon the black earth was perhaps mostly formed before the Tjerimai appeared as a volcano, a considerable part of the parent material must have originated from the marls, although at the same time a considerable quantity of fine ash has been mixed with it.[128] However this may be, at present we do not find any of the original minerals except quartz. On the other hand the black earth at present contains a quantity of lime and iron concretions, the latter in the form of hail iron ore. In this connection Ledeboer writes:[129] "This soil is very difficult to work and must be classed with the heaviest in Java. Practically it is heavier than the figures for the hygroscopicity and those for the mechanical analysis would indicate. This must

127. Pp. 165-170.

128. Verbeek and Fennema, <u>l. c.</u>, p. 459--state that the older, fine tuffs at Baribis village, between Kadipaten and Madjalengka, contain pumice stone fragments with many black mica crystals. That gives the impression of a material richer in silicic acid than the later andesites of the Tjerimai.

129. Ledeboer, <u>l. c.</u>, p. 768.

Photo by L. P. de Bussy

Fig. 218. Cheribon. View from a point south of the Kota, looking north. In the right foreground dry, unirrigable land, bare and treeless. Beyond, to the left, the alluvial plain, with paddies and sugar cane cultivation.

apparently be ascribed to a still not clearly understood chemical composition of the soil through which in the wet condition it approaches a tenaceous, doughy mass." Then Ledeboer refers to the analyses by Marr, who found relatively much Na in soils of this sort. Yet at the same time his own analyses do not include any figures for Na. Without wishing to underestimate the influence of a possibly high Na content I would like rather to remind the reader what has been said above on pages 526-528 where the possibility was suggested of a different course of the weathering, in this sense, namely, that with pH's of 7 and higher, not kaolin but rather montmorillonite forms, which is the clay mineral which shows especially high plasticity, much swelling and shrinking, and a high absorptive power. However this may be, only further thorough research will be able to explain whether or not Ledeboer, with his remark about "a still not clearly understood chemical composition," has correctly expressed the true conditions. Perhaps also the explanation will be found as to why this "rantja minjak," as all black earths of this nature, is so extraordinarily poor in P, and where has all the P gone which originally could not have been lacking?

* * * * *

Now in turning our attention to the higher slopes on the Tjerimai, where the cultivation of tea has been opened up, the reader will note a difference between this tea district and the more westerly ones of the Priangan. In the Priangan a dry season is indeed to be observed, but in general it is not severe. But everyone familiar with Cheribon, however, knows the "koembang," a strong dry wind which in the east monsoon blows around the Tjerimai and dries out the soil. This is perhaps the reason why on

Photo by L. P. de Bussy

Fig. 219. Cheribon. View from a point south from the kota, looking southeast. Old road from Cheribon toward Koeningan. In the foreground the flat basalt flow, called the Cheribon volcano, with some dusty, grayish black soil on the surface. Unirrigable dry land. In the background Mt. Tjerimai.

slopes of this mountain one hears so much more about the hindering tjadas or padas layers and in the course of excavations also sees it relatively close to the surface. How near to the surface it is depends upon the degree of erosion in recent as well as in earlier times. Especially higher up, these soils are very sandy. Deuss[130] records a number of analyses, of which the following may be given as averages:

2--1/2 mm.	1/2--1/10 mm.
9%	53%
100--20 mu	**less than 20 mu**
29%	9%

We can thus be sure that heavy showers of a small total amount of water are entirely absorbed and percolate downward, while unless the land is heavily terraced, heavier rains will erode much sandy surface soil. At about 1,200 m. these sandy soils are not too humous, according to the analyses only 2 1/2 to 4 1/2% organic matter. But of mineral plant food substances there is no lack, not even of P, which on the plain is low. Hence if the roots are not hindered by tuff layers and are able to attain a good distribution at desirable depths the conditions for growth are by no means unfavorable. If an extra dry year occurs, however, the plants stand for a long time without rain.

* * * * *

CENTRAL JAVA

In accordance with what has already been stated repeatedly in this study, which is from the viewpoint of soil science, we

130. J. J. B. Deuss, Theegronden Van Java en Sumatra, Meded. Thee proefst LXXXIX, pp. 82-83.

by no means intend to limit ourselves to the political boundaries of the Government of Central Java. So, for Central Java we can better differentiate the various subdivisions if we draw as boundaries the meridians of Cheribon, Semarang, and Soerabaja. First we shall consider the westerly part, that between those of Cheribon and of Semarang--Jogjakarta

WEST-CENTRAL JAVA

In this part of Java also, volcanoes are the factors which have brought about important soil differences. Some important ones are Mt. Slamat, the Diëng mountains with Mts. Sindoro and Soembing, Oengaran, Merababoe, and Merapi. These volcanoes are built upon and transversely across a ridge of older volcanic rocks (m_1 of Verbeek and Fennema) running east and west. While to the north and to the south this ridge is flanked by Miocene marls and limestones.

Even now these older m_1 rocks, principally andesitic breccias and conglomerates, are exposed at the surface over a large area. For example, between the Slamat and Priangan volcanoes and between the Slamat and Diëng Mountains. Likewise exposures occur between Bandjarnegara and Poerworedjo, while the Djamboe mountains between the Sindoro and Oengaran also belong to this group of old rocks. In a line from Penjaloe (East Priangan) via Meloewoeng to close to Maos, the marls and the shales, clay slates, and limestones associated with them form the greatest continuous single geologic region in the southwest. Smaller bodies are in Banjoemas, Keboemen, Poerbolinggo, and Bandjernegara, as well as at Bandjarhardjo, Pangka, and in Kendal.

Between Banjarnegara and Keboemen, projecting up through the Miocene is a complex of much older rocks consisting of quartz sandstones, diabase, gabbro, serpentine, quartz porphyry, hornstones, slates and even crystalline schists. This "window" testifies to the fact that in the deeper portions of Java there are similar formations and rocks as elsewhere in the Archipelago, as for example on Sumatra, Borneo, Celebes, etc., where they are found on a larger scale. Here in Java there is only a limited exposure, about 30 km. long and averaging 10 km. wide. While geologically this region has already been thoroughly studied,[131] yet not at all from the standpoint of soil science. Consequently, although without doubt interesting soil types can be expected I do not have the data upon which to base a discussion of the soils.

Apart from this small, special region, all of the parent rocks of the soils belong to relatively simple groups. (1) The so-called marls, consisting of coarser or finer quartz grains, clay and lime, in varying proportions. (2) There are also intermediate to basic effusives, older ones in the form of compact rocks, or conglomerates and breccias cemented by silicic acid, and younger ones in the form of lava streams, tuffs, and volcanic ash.

The chemical composition of these rocks varies considerably (see Table 115). The Slamat rocks and those from the Merapi almost always contain more P than those from the Diëng Mountains. The augite hypersthene andesites of the Diëng and the Merapi contain more K than the Slamat basalts. The Diëng has less Ca than the two others. The Slamat basalts give high figures for Mg and Ti, also for FeO, while many Diëng and Merapi rocks show low FeO and relatively high amounts of Fe_2O_3. Besides, the variations among the rocks of one volcano or one volcanic complex are frequently greater than the differences between the rocks of different volcanoes.[132]

* * * * *

In West Central Java the climate is for the greater part quite wet. Only in the

131. See: Geolog. Kaart. van Java sheet 67 (Bandjarnegara) by Ch. E. A. Harloff, with explanatory text (1933).

132. In the most recent publication by R. W. van Bemmelen in: De Ingen. in Ned.-Indië (1937), IV, p. 134 there are still more analyses, among others of ultra-basic rocks which are not considered here, since they represent formations with very limited surface exposure and thus play a minimal role in soil formation (See Geol. Kaart van Java, 1:100,000 sheet 66--Karangkobar).

northwest corner and the southeast corner are stations for the measuring of rainfall, the records of which indicate a long, continued, quite dry season. The influence of the mountain is evident which runs through this narrow part of Java from east to west in such a way that between the Tjerimai and the Oengaran there is almost no spot where the height of the passes is less than 800 m. Only at Boemiajoe is there a lower pass, and then only with all sorts of bends in it. Both during the west monsoon as during the east heavy rains occur on the slopes because of the ascending air currents. Therefore while the rivers are short, they carry large quantities of water. Along the north coast there is only a little low land. If on the map a straight line be drawn from the north point of Indramajoe to the outermost point, north from the Moeriah, a portion of the Java Sea is cut off which is never deeper than 25 fathoms, or about 46 m. For that matter still very much farther northwards the sea is still but only little deeper than that. If the sea level here should fall only 50 m. that entire region would be land exposed above the sea, and then in the east monsoon without doubt just as dry a climate would prevail then as now is the case in north Cheribon. It might possibly be even drier since, as has been stated above, in the mountain ridge lying to the southeast there is almost no opening under 800 m. elevation. Thinking back to the times during which practically the entire area now occupied by the Java Sea was dry land, almost certainly the "wet monsoon" coming from the northwest must have been significantly less wet than is now the case. In short--the gigantic plain of the Soenda lands, because of its location in the rain shadow of the mountain ridges of Malacca and Sumatra in the west and of Java in the south, must have received but extremely little rain.[133] Perhaps there was so little rain that as a whole it was impossible for continuous, tropical high forest to develop. In extreme cases there may have been a vast prairie, even the grass of which died off in the east monsoon. Even so, along great rivers running through the region there must have been strips of much more luxuriant vegetation.

Coming back to the present time, we can only say that perhaps as a consequence of natural influences, or artificial encroachment by man, more and more land has been won along the north coast of Western Central Java.[134] And the farther this new land extends out the less rain it will receive than the hinterland lying to the south of it, even though the latter lies but a few meters above the sea. Then all the soil types which now exist in East Java in Central and Northern Cheribon, and in the northwestern point of Western Central Java will also develop here.

* * * * *

From the above it follows that in the part of Java here being considered the lixivia still greatly predominate. They are subaerial, brown and red on the convex portions of the land, the mountains, the hills, and the knolls of slightly sloping terrain, but there are amphibian and subaqueous lixivia that are gray, or grayish colored, more or less flecked with rust color, on the concave or flat terrain, the depressions, valleys, and in the lake and coastal plains.

The young Slamat, having been watered almost daily by brisk rains, so to say since its birth, has nothing but brown lixivium with an increasingly humous surface soil, the farther one goes up the slopes. That the Slamat has been in existence long enough to carry not altogether too juvenile soil, is shown by the deep erosion gully, a ravine cut down into a hard basaltic lava flow (see Fig. 220, page 620). The younger volcanic material has weathered

133. G. A. F. Molengraaff (De geologie der zeeën van Ned. Oost Indië (1921), p. 275 accepts that the average annual rainfall for the drainage basin of the two mighty streams which drained this region should have been about 2.7 m. which is about the same as the present day rainfall. It appears more probable that this average ought to be under 1 1/2 m. and for large portions even less than 1 m.

134. In order to see how rapidly this extension of the coast can take place, it is only necessary to compare the charts of today and those of 50 years ago, for example of the coast of Cheribon to and including Oedjong Pemalang.

Photo by E. C. J. Mohr

Fig. 220. The erosion gully of a mountain creek in a basalt lava flow from the Slamat (on its south-southeast side) near to Batoeraden, Banjoemas, at about 400 m. elevation.

Photo by E. C. J. Mohr

Fig. 221. Pekalongan. Near the Kaliwadas dam in the K. Genteng river; in the west bank can be seen a deposit of mixed, volcanic conglomerate (here 2 meters thick) lying on Neogene strata; which are marls with sheets of limestone in between. On the conglomerate is a reddish brown lixivium, a fertile soil; the tree roots go on down to the Neogene, but not into it. The river bed is of mixed colluvium of limestone and all kinds of volcanic rocks in gravel banks which gradually work down stream.

to a brown lixivium, even grayish, with here and there coarse sandy ash soil. But as a rule on the older andesitic conglomerates, breccias, and tuffs the brown color has already changed into brownish red and red. If we could look into the past we would probably see that in Tertiary time such older andesitic material must have been quite deeply weathered and through orogenetic movements had thereafter been submerged for a time under the sea, again later to emerge and be raised high above the level of the sea. By that time the soil, which was probably a brown lixivium, had become distinctly red. The iron hydroxides had been strongly dehydrated and crystallized as microscopic grains (about 1 mu or smaller) of goethite or hematite. The clay minerals had probably also been transformed, recrystallized to another mineral. Stated briefly, then, such a "red lixivium" is indeed entirely different from another red lixivium, lying perhaps a hundred or 200 m. higher, which had never come into contact with the sea. Both are senile in the sense that there are no more weatherable minerals in either of them. That is, providing no fresh ash rains have ever fallen onto them. But red land, for example that of the Siloewok Sawangan plantation lying on the north coast between Weleri and Batang, submerged in the sea water, would during its bath in the sea become saturated with such bases as Ca, Mg, K, and Na and moreover would be altered physically in the direction of a strongly increased plasticity and stickiness, and possibly also a greater power of absorption. In general terms we may state the matter thus: red lixivium which never came into contact with the sea nor has originated from marine (calcareous) sediments is less plastic and less sticky, has a smaller power of absorption and is more intensively leached out than red lixivium which has been in close contact with sea water. It is desirable to thoroughly test this hypothesis by rigorous analytical methods on carefully chosen soil samples.

Deep soils do not occur on the marls and allied marine rocks, especially when they lie somewhat high and on rough terrain, for the soil is eroded off before it can develop to any considerable depth. On such parent materials this is a very widespread phenomenon, because the material swells when it takes up water. Becoming plastic, it slides toward the rivers, which when in flood sometimes carry with them a thick pale gray porridge of soil and water (see Figs. 213-217 and 225). In the lower stretches, as along the coastal plain, but also higher, as in the Serajoe plain,[135] and in general on paddies that pale gray fine sediment is again deposited. In such deposits the grain size as a rule lies between 20 and 1 mu thus a heavy loam, which make the cultivation of these soils peculiarly difficult.

As already mentioned in Part I, these Marl loams consist especially of three constituents: fine quartz powder, colloidal clay, and sometimes also calcium carbonate. If the quartz powder predominates, then as a rule it is somewhat coarser, namely from 5 to 50 mu, which makes the soil somewhat more pervious, but chemically speaking of course poorer. If the clay predominates, then it is richer chemically. It is especially so if it has been formed from weakly leached marl material and thus also still contains $CaCO_3$. But then the clay is also flocculated and slides off seriously. This is the despair of farmers, and it is practically impossible to cultivate paddy on such soils. If, however, the lime is leached out, then with reference to the other plant food materials the clay soil is also impoverished and moreover, the perviousness will have been reduced to a minimum value or even to zero. On pure marl soil types always one or the other of these reasons continues to cause worry. Only the mixing in of volcanic material brings relief. Whether the ejecta is coarse sandy, or whether it is finer, if only it be rich in iron hydroxides, it increases the perviousness of the soil and therewith the opportunity for the plant roots to grow down through it and to find water and food. Volcanic admixtures, particularly juvenile volcanic admixtures, such as fresh ash increase the fertility. The most effective quantity is a considerable covering of volcanic material (see Fig. 221, page 620).

135. Details regarding these phenomena may be found in: E. C. J. Mohr, Het slibbezwaar v. eenge riv. i/h Serajoedal, enz., Meded. Dept. Landbouw Buitenzorg. No. 5 (1908).

The above referred-to soil types have been described in more detail by Szemian[136] on the explanation accompanying sheet 58 (Boemiajoe) of the Geological Map of Java. From this description we may here mention that the tuffless rocks or those very poor in tuff give rise to soils which slide and bulge out, while those which contain tuff or are rich in this material do not. Further, the former sorts of soil are poor in K, while the soils from the tuffaceous rocks, however, are moderately to generously supplied with K. Also the content of Mg rises with the content of tuff. The perviousness likewise, increases, being correlated with the iron content and on the higher mountain slopes with the humus content.

As a particular point, it may be mentioned that in Upper Banjoemas, as also at Wonosobo, I found red lixivium developed from dark green Miocene marine marl tuffs with many Foraminifera. Though there was no longer any trace of $CaCO_3$, in carefully prepared thin sections under the microscope red lixivium still showed clear sections of Globigerinas. Only the empty forms had thus been completely preserved by the surrounding soil material, iron oxide hydrates, etc. indicating that while there had been no mechanical disturbance, the chemical leaching had been complete. This may be compared with feldspar forms which remain so sharp even in weathered crusts that although the feldspar itself has completely changed, one can still accurately measure crystal angles.

* * * * *

If we now fix our attention upon the utilization of the soil, upon the agriculture and upon the population of Western Central Java, then two natural factors generally characterize it. The first is that adequate water is universally present, whether it be as continuously excessive rains, or as continuously abundant supplies of irrigation water. The second factor is that almost everywhere virile to even juvenile soil types occur, and even where these are more senile, the irrigation water comes from juvenile, mountainous regions rich in volcanic ash.

The influence of the Slamat as a young volcano in producing high yields from the soil is not confined alone to its slopes, but also extends out over the northern coastal plain, from west of Brebes to east of Tjomal. As to what the Kali Goeng River, for example (see Fig. 222, page 623) signifies in that respect, the figures of the density of the population (in 1930) of the following districts show:

	inhabitants per km.^{2}	
Slawi	900	
Adiwerna	1638	(without a large village)
Tegal	1478	(without the municipality of Tegal: 1052)
Brebes	710	

The Kali Tjomal raises the figures for Tjomal and Pemalang to about 700. In between lie:

Djatinegara, with still some marl terrain:	260	inhabitants per km.^{2}
Soerodadi with	440	" " "

Towards the south upon the slopes of the Slamat there are also such densely inhabited districts as these:

Poerwokerto	709	inhabitants per km.^{2}
Soekaradja	837	" " "
Poerbolinggo	766	" " "

Among the high figures for density of the population, the Merapi takes its place as a volcano still active today. Note the density of the population of these districts on the slopes of the Merapi:

Magelang (without the town)	651	inhabitants per km.^{2}
Moentilan	653	" " "
Salam	581	" " "

On the opposite side of the Progo, on the contrary, where fresh ash can reach the soil only through the air, Salaman has 408 inhabitants per km.^{2} and Nanggoelan has

136. J. Szemian, Korte agrogeol. beschrijving, achter: Toel. b. blad 58 (Boemiajoe) van de Geol. Kaart van Java (1934).

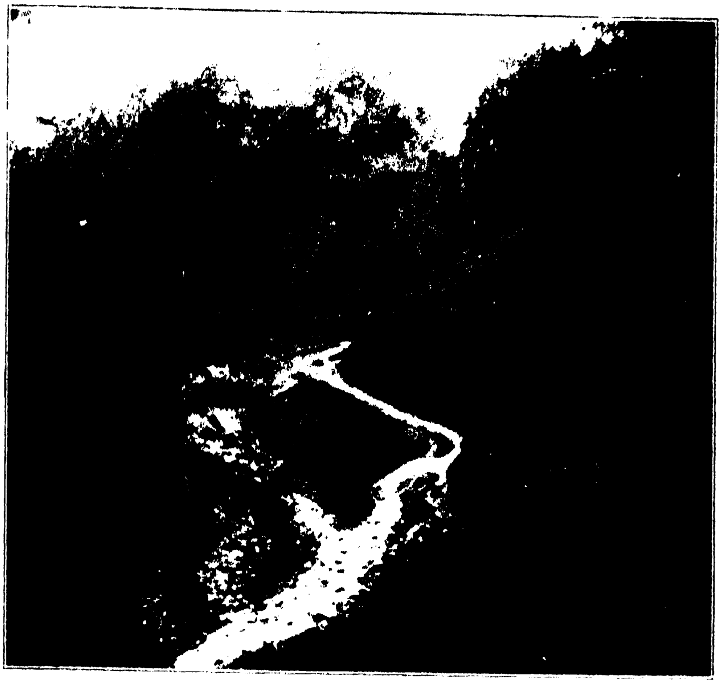


Photo by E. C. J. Mohr

Fig. 222. Tegal. Here at Kalibakong on the K. Goeng, the stream has cut about 100 m. deep into Neogene strata which are superficially obscured by a young volcanic covering of a few meters. The Goeng River carries much Slamat efflatas toward the north and is thus the cause of the fertility thereabouts.

378 inhabitants per km.^{2}.

While these are respectable figures, yet they are very much smaller than of the districts on the slopes of the living volcano.[137]

The entire Southern Coastal plain, from Tjilatjap on to the Goenoeng Sewoe, has been built up entirely from alluvia and colluvia from the large rivers. The Serajoe River carries the Diëng and Slamat products toward the sea, the Bogowonto and the Progo carry Soembing products, and the Progo and the Opak carry Merapi products. Between the Serajoe and the Progo there are also a half dozen shorter rivers which flow into the sea, of which the Kali Bengawan, the K. Idjo and the K. Lohoeloh or Loekoela are the most important. But since these have their sources in older mountains their sand and silt are of less value. From the west toward the east in the low plain the soil differences, however, are less than the differences in the materials which these rivers carry off. This is because the plain is not built up directly by the rivers, but indirectly, via the sea. It is especially during floods that sand and silt are carried by the rivers at great speed out of the hinterland into the sea. For example, during high water in the

137. For comparison it may be here recorded that also in Europe around living, fertility-making volcanoes the population rises. The density of the population of Italy in 1931 (See: Aperçu d/l démographie d. divers, pays d. monde (La Haye, 1932), Van Stockum) as a whole amounted to 133 inhabitants per km.^{2}, for the province of Campania 258, and for the district Naples (with Vesuvius) 663. Sicily with an average density of 154, Catania, south from Etna, has 190 and Messina, to the north of it, 183. All other provinces have lower figures. Catania is the largest city of the Island.

Progo, it is interesting to see, as from the height of the Goenoeng Sewoe, how the sea for many kilometers out in front of the mouth of the Progo is turbid and colored brownish red. Because of the currents the greater part of the fine silt is carried far out to sea and lost, but the sand sinks rapidly, is moved along by the shore currents and mixed with the sand from the other rivers, so that along the whole coast from Tjilatjap to Parangtritis (South Jogja) quite the same sort of mixed sand is thrown up on the beach. From that sand the wind blows up dunes. And since the prevailing winds are the east-southeast trades, in the west one finds more ridges parallel to the coast than in the east. Near Tjilatjap about 14 can be counted, near Kroja as many as 20. But farther east, however, especially about Koetoardjo and farther, these sand ridges are less conspicuous. The elevations in the flat land are no longer the dune ridges but the banks of the rivers. If the topographic maps (1:50,000) of this whole region be laid down and fitted together, one can see at a glance more clearly than can be described by words, what portion is river formation and what is dune formation. The relationships are similar and as clear as were pointed out for northern Atjeh (see page 440 of this book). It is of course obvious that the inhabitants build their houses on the slightly higher, dry ridges and use the low land for paddy. Also the roads all run along the ridges, through the very long stretched-out villages. Consequently, where the map indicates long green village strips running east and west the locality is one of younger or older coastal formation. But where the green strips run more or less meanderingly north and south the elevations are old river banks.

The sand of the dunes, as well as that of the river banks, however, is for the most part of young volcanic origin, consisting of basaltic and andesitic fragments and loose crystals of mostly calcium-rich plagioclase, hypersthene, augite, some hornblende, as well as quite a bit of magnetite and ilmenite. The last two minerals, also called magnetic iron sand and titanium iron sand are, however, very heavy. They do not blow so easily and for the most part remain on the beach. The other, as dune sand, once it gets a couple of meters above the sea and thus above the reach of the sea, weathers rapidly and forms soil, so that vegetation can establish itself. With vegetation growing on it the dune ridge becomes fixed.

The sandy ridge weathers subaerially. The soil formed is rich in iron, thus pervious. The climate is continuously wet; consequently the sand ridges gradually go over into brown to brownish red lixivium. Except a little quartz and some more magnetite and ilmenite in very fine grains, all the minerals weather.

Between the ridges the soil for the greater part is under water. There it weathers to a gray, subaqueous lixivium or at least to amphibiously weathered, gray paddy land with brown markings. Since between the ridges, besides rain water there is also silt laden water flowing directly from the rivers, the fertility continually increases in spite of the intensive rice cultivation which otherwise in the course of time would decline. This explains why the paddies of this region usually yield more than 52 quintals per hectare and if then the east monsoon also does its share, there can even be obtained a second harvest of about 35 qu./ha.; thus together more than 87 qu./ha. per year. Of course these are maximum yields. But average yields are so high that it is not surprising that this whole coastal stretch, the so-called Oeroet Sewoe is very prosperous and the density of population varies between 600 and 800 persons per $km.^2$.[138]

In some places near Koetoardjo the population has developed the most intensive form of soil utilization of which I know. Lands which lay on the limits of irrigability, thus by nature were associated with amphibian conditions, have been divided in such a way that one part has been excavated until the surface can be kept submerged and thus can be planted to paddy. The excavated earth has been placed on other portions of the fields, so that the difference in level becomes 1 to 1 1/2 m. making the elevated portions little reddish brown fields or plots sufficiently well drained so that maize, cassava, beans and other crops are

138. See in this connection: Census (1930), dl. II: Inh. bevok. Midden-Java en Vorstenl. (1934), p. 10.

Photo by E. C. J. Mohr

Fig. 223. Kedoe, near Koetoardjo. Through excavating of certain plots and building up the adjacent ones the natives convert partially submerged lands into paddies which can be maintained submerged and beds of "tegallan" land, which remain above the surface of the water and in this case are planted with maize. On the low dikes about the land are planted bananas and other fruit trees.

cultivated on them. If the level had not been raised there would have been too much trouble from ground water (see Fig. 223 above).[139] Possibly the original reason for this enormous moving of earth for agricultural purposes was because of a lack of land for the dense population. But it was doubtless also due in no less degree to the fact that the method was successful economically, since both the wet paddy and the dry, artificial upland soils still produce good crops making the work worth while. Had this intensive cultivation not been possible the land would not have supported so many people and many would have felt obliged to emigrate. Ultimately, however, some of the population will have to emigrate since the productivity of the soil cannot be raised to an unlimited degree. Meanwhile there is no doubt that through appropriate fertilization still quite a little increase over current yields can be obtained in a number of places; especially where the hinterland, principally older rocks, is covered with red lixivium. There the rivers and smaller streams do not give an adequate increase of fertility, for though the allochthonous soil is quite good physically, and there is an ample supply of water, the land is poor, in most cases primarily in P, but also in N and locally in K, Ca, and Mg.

* * * * *

139. In the low, wet paddy plain of Central Thailand (Siam) a similar method of ridging and ditches is used to make artificial upland soils for the extensive fruit and vegetable gardens around Bangkok. The Chinese vegetable growers plant two rows of paddy in each ditch, but in the shady orchards the chief value of the ditches aside from facilitating irrigation and drainage is to supply annually quantities of mud for fertilizing the soils about the trees. --R. L. P.

Now a few lines regarding the extreme southwestern part of Western Central Java, that lowland and low hilly land which includes the Kinderzee stretching out between Bandjar and Tjilatjap.

The hilly ridges referred to are Miocene, now folded they belong to the "marl stage," but diverge markedly from the marls, for the content of lime is almost always low, while the content of clay and fine sandy volcanic material is high. Verbeek[140] repeatedly mentions claystones and fine andesitic sandstones, even the "white kaolin rocks, which do not effervesce with HCl." According to the analyses by Cretier a "white claystone" from Larangan (north from Tjilatjap) had the following composition (see Table 130) and consisted "entirely or practically entirely of uncolored mica filaments and flakes."

Table 130

ANALYSIS OF A WHITE CLAYSTONE

	in %	in M. E.
SiO	64.17	88
Al_2O_3 (+ TiO ?)	13.19	10 1/2
CaO	3.42	5
MgO	3.16	6
H_2O	15.33	70
Total	99.81	--

Apparently iron and alkalies have been leached out, this has perhaps been followed (in sea water) by an absorption of Ca and Mg, followed by crystallization. It appears probable that the original parent material was a silica-rich, iron-poor, colorless glass in dust form. It is likely that under such white earthy layers as these good bleaching earths are to be found.

Subaerially weathered by the heavy rainfall of this region, pale reddish kinds of heavy clay and loam are found. As a result of the erosion of these soils from the low hilly land, heavy loams and clays have been carried out onto the low plain to the west and southwest. These soils are suitable for moderately fertile paddies. But the cultivation of sugar cane in the plain of Madjenang was not a success.

From the Priangan mountain and hilly land lying to the west the low plain has received and is still now receiving better silt. It is especially the Tjitandoej River which brings this sediment. On the western low hills and even in the northwest part of the plain there are also extensive rubber plantations. Gradually working out from the edges toward the center, the low marshy plain is being conquered. Great swamps still lie on both sides of the Tjitandoej, but it is evident that as the result of man's activity those on the west side will be the first to disappear because the soil there promises more than on the other side. It is interesting to see on the map[141] that just south from the wayside railway station Tjilongkrang, the Tjitandoej formerly flowed on a bit farther eastwards and then turned southwards. There in the plain the villages stand upon the old river banks and all the land lying in between has been made into paddies. If, following this natural example, the Tjitandoej just beyond the Langan plantation should be diverted south-southwestwards into the Lakbok Swamp, possibly in a few tens of years this swamp might silt up so much that it also would become useful land for paddy cultivation. It is likewise true for the smaller Bioek Swamp, which lies south of there. Thus in Central Java, before reaching the muddy lands around the Kindeł lake, several thousand hectares could gradually be obtained for colonization.

* * * * *

Where in the southern coastal plain just as in the northern coastal plain, as a result of mixing of the fine marls taken from quartz powder and marl clay, allochthonous soils have been deposited as very heavy clay loams, soils have developed which are physically and mechanically difficult to handle. In the east monsoon these are much less adapted to second crops. Therefore if the native farmer is at least certain of enough water, he would rather put in a second planting of rice than upland

140. Verbeek and Fennema, l. c., pp. 396-401.
141. See sheets 42/XLIB, 42/XLID and 43/XLIC (1928-1930) of the Topographic Map 1:50,000.

Table 131

RICE YIELDS AND SUGAR CANE AREAS IN WESTERN CENTRAL JAVA

Northern Coast	Paddy quintals per hectare	Sugar cane area: % of the paddy area	South coast and Banjoemas	Paddy quintals per hectare	Sugar cane area: % of the paddy area
Sindanglaoet	17.3	14.0	Adiredja	18.4	--
Losari	19.7	24.6	Kaliredja	18.2	8.3
Tandjoeng	19.7	2.8			
Brebes	19.8	12.9	Soekaradja	16.0	11.9
Bantarkawoeng	18.9	--	Peorbolingga (Bjms)	17.2	11.9
Tegal	19.0	13.1	Poerworedja	15.2	17.0
Adiwerna	18.4	21.5			
Slawi	18.8	31.3	Pitoeroeh	18.1	11.3
Balapoelang	17.4	11.3	Poerworedjo	19.8	12.9
Pangka	15.3	17.4	Poerwodadi	14.8	14.1
Soerodadi	21.4	11.8			
Pemalang	18.5	13.6	Wonosobo	18.5	--
Randoedongkal	18.6	--	Parakan	21.7	--
Tjomal	17.6	12.0	Tjandiroto	18.7	--
Wiradesa	14.4	20.2			
Pekalongan	15.2	18.3			
Kedoengwoeni	12.3	16.4			
Batang	13.8	17.5			
Weleri	14.9	12.6			
Kendal	15.4	22.9			
Kaliwoengoe	17.7	13.3			

crops which have difficulty in penetrating the very heavy clay in order to extract from it adequate water and plant food substances. In the south, especially in the districts of Kroja (formerly Adiredja), Soempioeh (formerly Kaliredja), Rowokele, Gombong, Poering, Pedjagoan, and Koetoardjo, more than half of the fields produce annually two crops of paddy.[142] In the north, naturally double cropping to paddy is done only in those districts which either themselves, or in their hinterland have adequate rain in the east monsoon. Those provinces in which a good deal, though perhaps not more than half the paddy land gives two crops of rice a year, are Kadjen, Soebah, Weleri and Kaliwoengoe.

The rice yields are often satisfactory, but still not extraordinarily high. They are not nearly as high as in a number of districts of East Java. According to Scheltema[143] in a number of districts of the part of Java here being considered the average rice yields are more than 18 qu./ha. dry gaba = 24 quintals per hectare dry paddy = about 30 qu./ha. wet paddy. In how far these higher yields are the result of the intensive working of the soil, the good irrigation and heavy fertilization which is a part of the associated <u>sugar cane cultivation</u> may appear from Table 131 above, in which there are also included districts according to the tables with the above-referred to Agricultural Atlas[144] in which during the monsoon 1921/22 more than 10% of the paddies were also used for growing sugar cane (see Table 131, above).

It thus appears that there are some districts with high rice yields with little or no sugar cane--of those Bantarkawoeng, Randoedongkal, Wonosobo, Parakan and Tjandiroto are located quite too high for sugar

142. Landbouwatlas Java en Madoera, Meded. Centr. Kant. Statistiek 33 (1926), text and tables.
143. A. M. P. A. Scheltema, Rijstproducties op Java en Madoera, Landbouw IV (1929), p. 782 ff.
144. L. c., Text and tables, p. 78 (1926).

cane cultivation. The two first-named are very productive because of the Slamat, the three others because of the ring of volcanoes, the Goenoeng Prahoe, the Sindoro and the Soembing from which their irrigation water comes. In the northern coastal plain Tandjoeng, with a high yield of rice, has a very small area occupied by sugar cane; doubtless this can be explained when more detailed soil sampling and mapping has been carried out. We have already mentioned the case of Adiredja (at present called Kroja). The climate is too wet for sugar cane and the population is prosperous with the two crops of rice per year which are very common here.

There are also the districts with more than 10% of the paddy land occupied by sugar cane and with average yields of rice. Definitely poor yields of rice, apart from the occasional effects of diseases and pests, do not occur in this group. From Wiradesa to Kendal is a series of relatively low figures. The mountains, which one sees from the coastal plain in this region have all been quiet somewhat longer than the Slamat and the volcanoes in the southeast. On their slopes, because of the heavy rainfall and the long time since the last rejuvenation, are intensively leached soils. They are mostly brownish red lixivium which although it might not be called entirely senile, yet certainly is no longer juvenile. Thus there are many good reasons why the rice here does not give the highest yields. Yet this soil, especially in its silted up, alluvial form, is very suitable for sugar cane. Physically it is good and chemically it responds very well to fertilization. From olden times Pekalongan has been known for its "purer juices" in comparison with other cane districts such as the Principalities of Central Java, and the Eastern Cape which likely give more sugar but also give more trouble in the clarification of the sugar cane juices in sugar making. This is without doubt a soil question.

Finally there are districts with high rice yields which at the same time have a generous proportion of the paddies planted to sugar cane. From Brebes to Pemalang there are six of these which form a series along the north coast. This is just that portion of the coast where the rivers, having their source in the Slamat, bring down good irrigation water. With adequate irrigation water, Losari also has the advantage of a dry climate. In the south, Pitoeroeh and Poerworedjo profit from the presence of the sugar mills, for the fertilization of the sugar cane is also of advantage for rice. Poerwodadi lies somewhat lower and has more old swamp land, as well as more rain than the two previously named districts (see the map, Fig. 6).

Taken as a whole, it appears that the districts of Western Central Java where there is sugar cane cultivation of some significance also have moderate to high yields of rice. But the contrary is not true. The margin, in so far as it relates to climate and soil, is broader for rice than for sugar cane.[145]

Besides rice and sugar cane in this part of Java, quite a good deal more <u>maize</u> is planted than in Western Java. There, in Western Java but 3% of the total cultivated land is occupied by this crop, while in Pekalongan, Banjoemas and Kedoe maize occupies about 25%.[146] On inquiring as to where most of this crop is grown, we find it is entirely in the higher stretches, where it occupies 40-80% of the cultivated land. As to nature of the soil, I have not been able to learn anything. Indirectly we do have some hint, in that an intensive native tobacco cultivation, such as is carried on in and around the Diëng mountains and the basin of the Kedoe requires much manure, thus much livestock (horses), thus much animal fodder, and maize provides a very suitable supply. The cultivation of tobacco is carried on in just those localities mentioned, on more or less juvenile ash soils, and the maize grows on, or in the neighborhood of, these soil types. In as far as I know, the question as to whether the leaves and stalks of maize produce an especially good stable manure for the use of the tobacco culture has never been particularly investigated. The practical farmers apparently believe that it does.

145. This is indeed true in many regions of the Orient. --R. L. P.

146. Text and tables of the Agricultural Atlas, previously mentioned, pp. 107-113.

According to Nijholt[147] the average stem and leaf of maize contain about 0.6% CaO 1.6% K_2O, 0.35% MgO, 0.2% P_2O_5, and only 0.1% Na_2O and 0.1% Cl. Consequently the manure from animals fed this fodder will most probably be rich in K and Ca, with but little or no increase of Na and Cl. These are characteristics which can only improve the burning quality of the tobacco.

The cultivation of tobacco in the higher portions of the mountains of west Central Java must be of great significance because annually in Kedoe about 28,000 hectares are planted to it. This is twice the area planted to this crop in the East Coast of Sumatra. The principal concentration of tobacco cultivation is in the subdivisions Magelang, Temanggoeng, Wonosobo. While in the districts Garoeng, Parakan and Tenanggoeng tobacco annually occupies between 20 and 30% of the total area of cultivated land.[148]

In the whole of Banjoemas annually more than 9,000 hectares are planted to tobacco. This is much more than all of the tobacco area of the Central Javan Principalities. The district of Batoer with 6,000 hectares and about 40% of the total of its cultivated land in tobacco takes the cake. It is notable that these tobacco districts have loose, light, juvenile volcanic ash soils. The relatively high K and relatively low Ca content of Diëng rocks (see Table 115, page 560) is particularly notable. The Merapi ash soils have somewhat less K and somewhat more Ca. Consequently the tobacco of East Kedoe "snows" more, that is, the ash does not sinter so well. In the first place those lands are obviously low in organic matter, consequently it is clear that farmyard manure is the indicated and also the most generally used fertilizer. People even keep horses especially to produce manure for the fertilization of tobacco.

A few fertilizer experiments of the Agricultural Section of the General Agricultural Experiment Station point in the same direction. With P fertilization no success was obtained, but with N fertilizers there was a marked effect. In some cases a deficiency of farmyard manure can be successfully made up by the use of ammonium sulfate.

The remarks above apply to rice, sugar cane, and maize, as well as to tobacco. The other crops of the native population do not show any clear relation to the type of soil on which they are produced. Because of the great density of the population, these crops are especially food crops, such as cassava, sweet potatoes, and all kinds of legumes.

With the exception of sugar cane, in this part of Java there is but little land available for European plantation cultivation. While there is still some land in the north, in the southern half, where even in the east monsoon adequate rain falls or else irrigation water is available, the natives have not left any useful land unused. Thus the land which can be and is occupied by plantations is definitely unirrigable, that is Tertiary hilly land. It is not on the marls, but on the red lixivia from the conglomerates and tuffs. Up on the slopes of the important volcanoes to the limits of the forest reservations, the native population is using practically all the lands which are not too rough. Tea plantations occupy a few spots on the Slamat, the Soembing, the Sindoro and the Prahoe which have not been reserved.

Most of the plantations lie in the Semarang district; the meridian of Pekalongan is about the limit. If we look at the map of Verbeek and Fennema, considerable areas of m_1 and m_2 are seen to be in Cheribon and Tegal as well as in Pekalongan and Semarang. Though in the east the m_1 regions can be planted, in the west, on the Koembang mountains, these formations are hopelessly rough and hence cannot be planted. Though analyses are lacking it further appears that in the west the m_2 contains more Ca-rich and tuff-poor marls, while in the east the soils on m_2 are richer in tuff. The lands of the former coffee plantations, which were in the east and not in the west and which by this time have practically disappeared, are now producing cacao, kapok, pepper, and nutmeg. In the west, where the less desirable marl lands

147. J. A. Nijholt, Voedingsstoffen, door een maïsoogst an den bodem onttrokken, Korte Meded. Alg. Proefst. Lb. No. 12. Also Landbouw 8, (1933), p. 519.

148. Text and tables of the agricultural atlas, mentioned above, pp. 107-113.

Photo by the Forest Experiment Station

Fig. 224. Margasari Forest, Pekalongan. Around the edge of this teak forest the soil has been trampled by cattle and afterwards eroded off. As a consequence the teak trees appear to stand on stilt roots. There has been a loss of about 1 meter of soil from around the nearest trees.

(see Fig. 224 above) are found, they are left to the Forest Service for planting teak, mahogany, and other kinds of timber.

Accordingly the four timber reservations lying in the portion behind the low coastal agricultural strip show striking differences. When we recalculate the figures of the Forest Service[149] to percentages of the terrain "apportioned for production" we get the following data in Table 132.

Unforested and only difficultly plantable areas (see Fig. 225, page 631) seem to occur most frequently on the marls of low fertility in the west, while the least occur in Kendal. In that respect Balapoelang is quite a bit better than Tjiledoek. Pemalang possesses a considerable area of marls (Djatinegara) covered with wild forest of no value, but it also has better lands. Of these four timber reservations, Kendal has by far the highest

Table 132

	Tjiledoek	Balapoelang	Pemalang	Kendal
Open terrain	27%	1%	4%	4%
Unproductive wild forest	23%	45%	59%	9%
Planted to teak	41%	43%	32%	84%
Not adapted for teak forest exploitation	9%	10%	3%	3%
Other kinds of timber	0.2%	1%	0.1%	0.2%
Afforestation	64%	89%	91%	93%

149. Verslag v/d Dienst v/h Boschwezen (1930), p. 75, table 1.

Photo by the Forest Experiment Station

Fig. 225. Marl region, the drainage basin of the K. Penggaron river, Semarang. Complete destruction of the soil through erosion following deforestation, burning, and pasturing cattle. The water of the river contains per cubic meter at time of floods as much as 45 kilos of material in suspension, almost entirely free from sand.

percentage of productive teak forest and the best afforestation.

For the land as a whole and the mountain land in particular it is likewise of more significance how the afforestation of the mountains is progressing because of its influence upon the runoff of water, the discouragement of spates in the streams, erosion of the mountain slopes, and accumulation of eroded material in the lower lands. From the aforementioned Report of the Forest Service for Pekalongan we can deduce that of the total area of the district about 3% is occupied by teak forest, 17% by wild forest, of which 11 1/2% is "natural forest," which is ordinarily called tropical high forest. Besides 2 1/2% is occupied by "insufficiently covered" forest which makes a total forested area of about 23%. That isn't very much, but still considerably more than the percentage of forest for all of Java, which

Table 133

	Pekalongan	Banjoemas	Kedoe
Teak forest	3 %	1/2 %	-- %
Natural forest (tropical high forest)	11 1/2 %	9 %	5 %
Rejuvenations (reforestations)	1/2 %	1/2 %	3 %
Other forest	8 %	1 1/2 %	1 %
Total forest	23 %	11 1/2 %	9 %
Agricultural lands for the inhabitants	58 %	60 %	79 %
Cogonals, grazing lands, villages, etc.	19 %	28 1/2 %	12 %

is but about 15%. From the above approximate summary expressed in percentages of the total area (see Table 133, page 631), we see striking differences between the different Residencies of Western Central Java. Banjoemas and Kedoe have relatively quite a bit less forest than Pekalongan. Kedoe has apparently much forest converted into agricultural land and cannot go much further in this direction. On the contrary, of the mentioned 12% unforested terrain, etc., 2% is fit to be reforested. Banjoemas has the most latitude. The 28½% of non-forested land can still be decreased through further occupation by native farmers and through further afforestation, especially in the upper drainage basins of the larger rivers, but also on marl lands, which cannot be used for growing annual native crops.

EAST CENTRAL JAVA

Via the district of Semarang in the north and Jogja in the south we leave the discussion of Western Central Java, and pass into Eastern Central Java. This subdivision lies between the north and south lines passing through Semarang and Jogja in the west and Soerabaja and Malang in the east.

As contrasted with an almost continuous range of mountainous land lying across the middle of the western part, this eastern part in its southern half has a series of separated volcanoes and an important series of ridges of Tertiary sedimentary rocks running through its northern half.

As contrasted with a climate with almost exclusively wet months (see the map Fig. 6) in the largest part of western Central Java, most of Eastern Central Java has a climate with a quite marked dry season. We shall here find soil types connected with the latter sort of climate, such soils as in Western Central Java are found only in the outer corners, such as Losari, Kendal, and Jogja.

Thus we shall see marked differences, but many points of similarity exist with respect to a number of climatic factors and consequently of soil types.

* * * * *

Let us first consider the volcanic parent rocks which have come from the series of volcanoes: Merapi and Merababoe, Lawoe, Wilis and the complex to which the Kloet, the Kawi, and the Ardjoeno belong.

Taken by and large, all these volcanoes have tapped magma from the same sort of vats. Pyroxene andesites are the *pièce de résistance* which may be differentiated further into augite andesites and hypersthene andesites. Closely related to these on the one hand are rocks which through increasing hornblende content via hornblende-containing pyroxene andesites, grade into definite hornblende andesites. On the other hand there are rocks which through increasing olivine content grade into basalts via olivine-containing andesites. Since the Kloet and the Merapi have been active during the present century there is a quantity of newer literature[150] relating to them; but about the Lawoe and the Wilis, there is not a similar abundance of information. Analyses, chemical[151] as well as petrographical, are also available for rocks from the Kloet, the Merapi and the Penaggoenan.[152] As parent rocks for soil formation there is not much which is new in these rock analyses. The only point really worth mentioning is that the products of the Merapi as well as of the Penanggoenan are relatively rich in K and that their FeO content is lower than average, certainly lower than that of the basalts.

Another question, however, is in

150. Literature, to which reference was also made in preparing the above, will be found in:
a--Verbeek and Fennema, Geol. Beschr. Java en Mad. (1896), dl. I.
b--Vulkanol. Mededeel. No. 2 (Kloet), No. 3 en 12 (Merapi), (1921 en 1933), by G. L. L. Kemmerling and M. Neumann van Padang.
c--Ch. E. Stehn, J. H. de Coert, Keloet, 4th Pacif. Sc. Congr. (Java, 1929), Excursion E 2a.

151. See Table 115 opposite p. 560.

152. Ph. H. Kuenen, Volcanoes, Part I of Contrib. geol. East Indies, Snellius-Exped., Leidsche Geol. Meded. VIII (1935), pp. 274-283.

how far the ashes, spread over a great area around the active volcanoes, have through this spreading and separation been subjected to a significant differentiation according to the size of the grains. Various points about this matter have already been mentioned (pages 35-36); and sometime ago, shortly after the last eruption of the Kloet (1919) J. Th. White went into this question with me[153] although at that time all the details were not published nor were all the experimental data presented. The conclusions of that research upon different Kloet ash samples of 1901 and 1919 as stated by White[154] were substantially as follows:

1. With increasing distance from the eruption point the ash which falls becomes finer and finer. Close to the point of eruption occur the greatest differences with respect to the proportions of gravel, sand, dust, and clay.

2. According to the grain size, taken by and large, the following constituents in the ash may be differentiated, from coarse to fine (coming down to a grain size of about 0.25 mm.): andesite gravel, Ca-rich plagioclase-crystals, small hypersthene columns, augite fragments, and little amphibole. In the particles smaller than 0.25 mm. diameter there are no andesite grains, less plagioclase, and less of the darker minerals already mentioned. Magnetite and ilmenite fall mainly in the fractions between 0.25 and 0.05 mm. and below 0.05 mm. there are practically none of these minerals. In the fractions below 0.1 mm. there are, besides plagioclase fragments, volcanic glass with fine and extremely finely exploded sand and dust predominating more and more in place of the previously mentioned constituents. This glass from the Kloet is colorless or at most very faintly tinted. From other volcanoes (Lamongan, Raoen) a much darker colored glass is known. In connection with the above it is clear that the color of the ash as a whole, which close to the crater was quite a bit darker gray, became paler and finer the farther it fell from the crater.

3. As to chemical composition, with the increasing fineness of the ejectas, thus with the increasing distance from the crater, the content of silica increases; on the contrary that of Fe, Mg and Ca falls. The content of the alkalies falls but little. The result of the differentiation may also be expressed as follows:[155] The finer ejecta of the 1919 eruption of the Kloet, which fell the thickest close to the crater and was thus the sandy material, in composition most resembled a basalt rich in Ca. Farther away the ash, taken as a whole, according to the chemical composition becomes more andesitic. And finally at a great distance it even approaches a trachyte in character, containing also a considerable amount of K and as high a silicic acid content as that of white pumice stone (see Tables 12-14, pages 25-26; 109-111, pages 520-523 and pages 520-522).

Thus it is possible to agree with Verbeek and Fennema[156] that "the material of the young volcanic cone mountains consists of andesite and basalt, in the form of fragmental products and in lava streams, while such glass-like products as peckstone, obsidian, and pumice stone with respect to the rocks with 'stony' ground mass are <u>very much less important</u> on Java." There is, however, a point I would like to add, namely, that <u>the magmatic differentiation of the fine ejecta in the atmosphere</u>, by the wind, can by no means be left out of consideration in this connection. It is indeed very possible that as a result of andesitic eruptions at a considerable distance, certain areas on Java have been repeatedly covered by fine ash which one may quite easily call acid, glass-rich silicic acid-rich, and iron-poor. Such materials hardened to tuff, analyzed by themselves, would without doubt be called acid tuffs. And the reason for including such a discussion in this book is that for the formation of the soil such a <u>material is</u> to be thought of as <u>entirely different</u> from the sandy ashes on the slopes of the volcano and the tuffs which are formed from them, both of which are rich in Fe-, Ca-, and Mg-

153. See: Verslag van de Ie Alg. Verg. der Ver. v. Proefst.-Personnel (Buitenzorg, 1921), pp. 75-99.
154. J. Th. White, l. c., pp. 84-93.
155. White, l. c., p. 93.
156. Verbeek and Fennema, l. c., p. 946.

containing dark minerals and thus may be called basic or at least intermediate.

Already I have pointed out (pages 8, 9) the general differences between basic and acidic rocks and tuffs for soil formation. Since then, particularly as a result of a statement by Rutten,[157] I have somewhat changed my point of view, in this sense that for soil formation on Java more weight should be attached to the content of Fe, Ca, and Mg in the parent material than upon its content of Si. As to the Fe content, a differentiation must be made between the forms in which this element originally occurs. In the course of the subaerial weathering on the mountain slopes magnetite and ilmenite are almost not attacked at all, thus in soil formation under such conditions they behave merely as indifferent sand grains. Olivine, augite, and hornblende, however, do break down. They supply the principal proportion of the iron hydroxides which color the soil brown and red. In the third place iron in the volcanic glass, if it be present, has this important effect, namely that it increases the weatherability of the glass, and, once free, increases the quantity of the coloring iron hydroxides.

With a given Fe content, say 4%, we can think of the following possible or imaginary types of volcanic ashes or tuffs:

1. Practically all the iron is present as magnetic iron sand and dust. Other "dark" minerals are as good as lacking. Thus much Ca and Mg cannot be present. The glass and the feldspar are on the acid side. The ash or tuff is pale, although somewhat grayish because of the black magnetic iron powder. Subaerial weathering produces a soil with very little iron oxide, thus certainly not an intensively brown or red-colored soil.

2. Practically all the iron is present in the form of hornblende. Consequently a larger proportion of Ca and Mg is also present. The plagioclase is richer in Ca, the glass is intermediate. The iron content in the hornblende is 40% of the whole. Then if the Fe content of 4% be accepted, it is 10% of the hornblende, making this mineral dark green. Consequently the rock is not grayish white, but a dark greenish gray. Subaerial weathering of this mineral results in a soil in which nearly all of the iron is precipitated. Hence it is an intensive brown color later changing to a reddish brown.

3. Practically all the iron is present in the form of glass. Such glass is then black or a deep dark brown when seen as small splinters. Black, basaltic pumice stone or lava, or cinders or slag. Weathering as above-mentioned, results in a dark brown to dark red lixivium.

Now when soils have originated from the materials mentioned under (1), (2), or (3) they differ in much more important ways than merely in color, for color, considered by itself, is quite unimportant. A blind man would not notice it any more than do the plants which grow upon it. In the first place there are the differences in the perviousness for water and air, as has already been mentioned on pages 131 and 139. Colloidal iron oxide when in the proper colloidal state and subdivided through the soil, makes the soil looser, more friable, and more pervious for water and air. When such a soil dries it forms no hard, stone-like clods, but of itself breaks down into a finely granular mass, predisposed, for example to "dry wash" (see pages 140-141). Such a soil is also easily intensively leached of such bases as K, Ca, and Mg which are so much needed by the vegetation.

In case (1), the iron is lacking. Thus in spite of the magnetic iron sand content there originates from these pale tuffs a pale, bright-colored, heavy sort of soil, which all too rapidly becomes impervious. But then the subaerial weathering is also finished and, with the climatic conditions such as often occur in East Central Java, namely a definite alternation of a rainy season with a dry season which continues for a long time, such a soil changes to an amphibian or an alternating weathering soil. Then the black soil can form, a soil which at the present time on Java is often called "tufgrauwaarde" (tuff gray earth). On pages 164-170, this soil type has been described in general

157. L. Rutten, Kritiek, Ind. Mercuur, 57 (1934), pp. 211-213.

terms. There is important specific information concerning it by Tollenaar,[158] who for example "found everywhere along the foot of the southern mountains" (in Soerakarta and Jogjakarta) "an older volcanic tuff which is sometimes composed of very fine material and then is white in color.[159] Most times layers of somewhat coarser, sandier, old volcanic material are deposited on it. Both sorts of rocks weather to a heavy, gray, cracking soil. Sometimes the sandier rock runs somewhat to a rose to brownish red" (it is thus apparently somewhat richer in iron, like the materials described under (2) and (3). Although somewhat less heavy than the bluish black, calcareous marl soils (they slake down less crumbly), this "tuff gray earth" is unsuited for tobacco. Both during droughts when the soil is a mass of hard clods, and during rains, when the soil runs tightly together, the structure is bad. It may also be remarked that only sporadically can we demonstrate in this rock any $CaCO_3$. Upon extraction with 23% HCl the lime content of the tuff gray earth is significantly lower than that of a lime marl soil."

This lengthy quotation shows the differences between this soil type and the many other kinds of brown and red soils, likewise originating from tuffs, but from other kinds of tuffs. From where the above-mentioned "fine, white tuffs" have come is as yet unknown. Nor is it known where the coarser constituents from the same eruptions fell and accumulated. The following general remark may, however, be added: If more or less fine, pale to white tuffs are found, then it is possible that these have originated from a single eruption from one or another volcano, which for this occasion obtained the material from a single mass of magma, richer in silicic acid and, for example, in K, but poorer in femic elements, something to which Verbeek has repeatedly called attention.[160] But also it is possible that the tuffs had had their origin in an ordinary magma which would normally give rise to an andesite but the "andesitic" ash, after the eruption had undergone a differentiation in the atmosphere.

It should not be forgotten that sea currents can bring about a differentiation similar to that which the wind can. Marine tuffs of very different, primary mineral content are found which indicate such a separation of material. Contrary to earlier theories, it is not necessary to always make submarine volcanoes responsible for marine tuffs. We have already considered a beautiful example of that in the Danau volcano of Bantam (see page 568 ff.).

Finally it must be kept in mind that large rivers also bring about a considerable sorting of ejecta. The gravel and sand are rolled over and over as colluvium on the bed of the river and sorted. Wherever it finally comes to rest, it is certain, on the whole, to be more basic, more femic and richer in iron than the original magma was. The pulverzied portion of the stream load is carried forward in suspension by the river on into the lakes or out into the low plain--in cultivated regions, however, also into the paddies. With rapid decrease of the current to almost still water the suspended silt settles out. Chemically its composition is then without doubt more acid, and richer than the original magma was in fine glass of pumice stone character. Differentiation brought about in this way has taken place long ago on a large scale, or again and again on a smaller scale, which comes to the same thing. Now there are such fine, white layers of ash hardened to tuff that upon first sight one is inclined to think of earlier eruptions of acid magma. Hence while that could have been the origin, it is not necessary to explain it in that way.

This is apparently demonstrated in Eastern Central Java, among other places, in the deposits of the Brantas, a river which has repeatedly received great quantities of andesitic Kloet efflata to carry forward and sort out. About this White[161] wrote as follows "Through his researches

158. D. Tollenaar, Agrogeologie en grondkaarteering v/h W. ged. v/h Vorstenl. tabaksgebied. Voordr. Klaten Proefst. Vorst. Tab. (27 Dec. 1930), p. 6. Idem, Bijdr. Kenn. agrogeol. grondtypen vorst. tab. geb., Meded. Proefst. Vorst. (1932), Table 73, pp. 16-24.

159. Floods of references!

160. See this book, pp. 23-25, 35, 495.

161. J. Th. White, l. c.; Versl. Ie Verg. Vereen. Proefst. Pers. (Buitenzorg, 1921), p. 97.

Table 134

QUANTITIES OF K AND Na IN EASTERN CENTRAL JAVAN SOILS FOUND BY DIFFERENT METHODS OF ANALYSIS

Soil Sample and Origin	Total content		In HCl extract		K_2O (3) in % of (1)	Na_2O (4) in % of (2)
	K_2O (1)	Na_2O (2)	K_2O (3)	Na_2O (4)	(5)	(6)
Tandjoengsarie--Sitoebondo--Idjen ...	1.53	2.90	0.220	--	14.4	--
Kandangdjati--Probolinggo	1.29	1.72	0.149	0.118	11.5	6.9
Gesiekan--Jogja--Merapi	1.03	2.00	0.129	0.188	12.5	4.4
Wonopringgo-Pekalongan	1.02	1.11	0.135	0.058	13.2	5.2
Poerwodadi--Madioen--Lawoe...........	0.75	2.16	0.025	0.049	3.3	2.3
Pandaän--Pasoeroean	0.75	1.93	0.065	0.091	8.7	4.7
Gending--Probolinggo	0.62	1.34	0.134	0.109	21.6	8.1
Wonosarie--Solo--Lawoe	0.53	1.67	0.062	0.074	12.9	4.4
Poerwoasri--Kediri--Kloet	0.48	2.58	0.050	0.179	10.4	6.9
Tuin Pakoentjen POJ--Pasoeroean	0.44	0.86	0.082	0.069	18.6	8.0
Modjopangoeng--Kediri	0.37	0.97	0.034	0.082	9.2	8.5

Marr has clearly demonstrated that the sugar cane lands lying to the east in the Brantas delta are richer in K than those clay soils found near to Modjokerto and these again are more plentifully provided with this constituent than are the sandy Kediri soils."

Measurement of the plant nutrient supplying power of the soil: Besides many determinations of K extracted in all sorts of ways, but giving far less than the total amount, these researches by Marr[162] also included a few total analyses (solution with HF) giving all the K.[163] But very unfortunately these few samples are not from the Brantas delta. The reader must not forget to keep in mind that Marr's conclusion mentioned above, is based on figures obtained by analyzing extracts made especially with HCl. That these analyses run approximately parallel with total analyses is indeed to a certain degree probable, but analytical determinations are as yet anything else but too abundant. This is illustrated by the following data from Marr (see Table 134 above).[164]

If the quantities soluble in HCl actually ran parallel with the total analyses, columns (5) and (6) would have quite constant figures. But such is not the case. When for about 10 soil samples out of the drainage basin of the Brantas river Marr recorded values for the HCl soluble K content, running from 0.14% (Boedoeran, East Soerabaja) to 0.05% (Poerwoasri, Kediri), then judging by the percentages in the above table it is just as probable that the total K content is 1/2% as 1%. Thus HCl extracts do not give us anything definite as to the total K so that direct determinations of total K are necessary.

For agriculture an important question is: What is the total amount of a certain plant food material present in soil? But a very much more important question is: How much of this food can the plant get possession of during the time it is growing in the field? While this is not the place to discuss this fully, it is worth while to briefly mention how in Java in less than half a century the conceptions regarding these points have changed and so have altered ideas about the soil and the researches which ought to be carried out.

Total analyses have been made only very sporadically. The method, whether it be solution of the sample with HF, or fusion

162. Th. Marr, Over kali en phosphorzuur in onzen bouwgr., Arch. Java-Suik. Ind. (1907), pp. 429-487.
163. L. c., pp. 437, 446-449.
164. Marr, l. c., pp. 456-458.

with soda, is expensive because of the platinum equipment necessary. This has deterred practically all researchers. In the Netherlands Indies "Codified Procedure for Soil Research" (1913) the method of total analysis of soil is not included at all.

For the past hundred years, researchers have chosen to use strong acids for extraction on the hypothesis that 1st such a solvent would quickly dissolve all the material available for the plants, and 2nd what did not dissolve in such a solvent had no value for the plants. Particularly as the result of the experience gained by cultivation and crop experiments, it gradually became evident, however, that both these hypotheses were incorrect. Sometimes the plants could not get possession of what the strong acids were able to extract, then again in a growing period of a few months the plants were able to extract more of a certain plant food material from the soil than the strong acids had. At the same time the biologists were contending that plant roots do not use strong HCl nor HNO_3. Hence the search for other methods continued, so that satisfactory answers to the above questions could be given at least roughly.

There now followed extractions with 2% or 1% citric acid. It was based upon the idea (indeed somewhat rough) that the effect of such an extractant would imitate the action of the roots upon the soil. Most certainly this method has given data of some value. Even so it became more and more evident that the results were too rough and uncertain an approximation of what the soil possessed of "directly assimilable plant food substances." Though in practice difficult to carry out, another step in advance was made by extracting with water containing CO_2. Then extractions were tried with pure water on the basis that since CO_2 which is generated in the soil is a factor in solution, CO_2 would also be generated in the soil samples in the laboratory. A recent example along this line is that of the Sugar Experiment Station at Pasoeroean which not long ago on the ground of the extensive and thorough researches by Miss Ir. Neep[165] abandoned the citric acid extractions for phosphorus and instead is using pure water extractions.

Obviously with progressively weaker extractants the solutions for analysis became more and more dilute, approximating the composition of the soil moisture and the natural conditions in which the plant roots carry on. While this is certainly an advantage, the analytical procedure to determine accurately the extremely small quantities of plant food substances becomes more difficult. In this, however, there is continual progress.

Finally in this summary I should add that as a result of the progress in colloid chemistry in the last quarter century the conceptions regarding the form and nature of the soil constituents have totally changed and consequently the ideas relating to the manner in which the plant food substances exist in the soil have also changed. In this book I have repeatedly referred to the microcrystal lattices and the mutual exchange possibilities of different bases. Without going into this matter further, suffice it to say that at the present time it is realized that it is not enough to determine a single base, such as K or Ca, in a number of soils and from this data to draw conclusions regarding too much or too little of certain bases in the soil. On the contrary it is necessary to determine the entire absorption complex thus K, Na, Ca, Mg, NH_4 and H before one will be in a position to judge the fertility and deficiencies of a soil in so far as it relates to this side of the question.

The inescapable consequence is much more work for the chemist but also greater certainty, because with more knowledge it is possible to draw more nearly correct conclusions. But--with all that, we are still not yet where we would like to be as to the knowledge of the plant nutrient supplying power of soils. For all these analyses, carried out in glass, give only statistical results. They indicate how much of a certain constituent is present, in total or in certain more or less relatively soluble forms. The taking up of this constituent by the plant roots, although this also takes place in such very small quantities at a time is, however, a dynamic process. The roots are continuously taking up substances and continuously the supplies of these substances must

165. G. A. Neep, Meded. Proefst. Java Suik. Ind. (1933), No. 20; Archief J. S. I. pp. 1031-1088; especially p. 1083.

be made good in the soil moisture surrounding the root tips. So long as the plant lives and feeds there must be movement; movement of the moisture itself, to supply the water needs of the plant; and movement of the food substances in the soil moisture to feed the plants. The growing of the root tips meets this movement half way, for these grow out in search of water and food. There must not only be moisture and food materials present, and the latter must not only be sufficiently soluble, but they must be able to move with sufficient speed. If they cannot do that, then the plants cannot get them, at least, not in sufficient quantity, for if the water and nutrients cannot move fast enough to the roots, the latter have to grow out to where the moisture and the plant food substances exist.

It is quite conceivable that while an analysis in the laboratory may indicate abundant moisture and plant foods in a soil sample, yet the plant languishes because the soil is too impervious, and/or it is too difficult for the roots to penetrate. This is not merely an imaginary case, for it has been established by experience that there are very heavy loams and kinds of clay on which sugar cane, cotton, and beans grow very well, but on which tobacco or peanuts do not yield a crop, because their roots cannot develop extensively.

As a consequence, all the abovementioned chemical analyses are not more than "half work." That is, we cannot do without them, yet on the other hand we must supplement them with research relating to the speed of movement of the moisture in the soil and the movement of the plant food materials in the soil moisture.

It is quite in order to mention here that the idea of the "making up of deficiencies" is no longer new. In the previously mentioned paper by Miss Neep (1933) it was stated[166] how according to the method of Von Wrangell-Andronikow "the speed of delivery" was determined. This was done by shaking a quantity of soil with 100 times as much water for a few hours, separating soil and extract, and repeating this several times; the extracts were then analyzed separately. This is indeed one step in the right direction, but still it does not go far enough. It does determine whether, after the roots have taken up the dissolved plant food materials from the soil moisture, the soil can again supply fresh quantities of those plant food constituents to the soil moisture and how much it can supply. But in this method the important factor of rate of movement of the soil moisture in the soil remains entirely out of consideration. It must be admitted Neeb has obtained significant results with respect to P, significant to the extent that better correlation was obtained between the figures of analyses and the results of the field experiments.

But this treatise[167] is also important for the Netherlands Indies because it marks a complete break with the old system of soil analyses by themselves[168] and because the emphasis is placed upon the necessity of first determining the kinds of soils as such, as soil types, then as carefully as possible to find the "normal" soil of each type and thereafter to analyze and to judge the soils. It is indeed too bad that during the years of the crisis the soil survey and mapping were so seriously retarded, otherwise there would have been a large amount of significant data available for this discussion.

The above digression regarding soil research in general was called for in connection with the review of soil types of young volcanic origin, which are found in Eastern Central Java.[169]

Whenever the parent material is really coarse and contains a large

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166-167. In addition to this and other papers by Miss Neeb, along the same line there are others by Brink, Demandt and others, published during the last decade by the Experiment Station for the Java Sugar Industry.

168. Compare: Result, chem. onderz. rietgr. Java door C. H. van Harreveld--Lako, Meded. P. J. S. I. 1926, No. 20 and the whole series of publications by O. Arrhenius in the Arch. J. S. I. (1927-1929).

169. Of course also elsewhere on Java, and elsewhere in the Archipelago; but particularly characteristic of the region we are now considering.

proportion of dark minerals, as on the slopes of volcanoes and in sandy river deposits, then because of the large amount of iron oxides, the soil formed from it through weathering is really quite pervious. The soil moisture can easily circulate in such a soil and the plants can, without much difficulty, develop an extensive network of roots. If, on the contrary, the parent material is fine and contains predominantly finely powdered pale glass, as in aeolian ash deposits at great distances from the volcano and in the fine alluvia close to the coast, then water movement is slow. Moreover, through the weathering which tends to produce a heavy clay, this condition does not improve. On the contrary the permeability approaches zero and the roots of many plants have the greatest difficulty in penetrating such a soil. As a result many kinds of plants, so to say, become discouraged because of lack of air in the soil.

In this connection the reader will see clearly that certain statistical figures regarding the content of N, P, K, Ca, etc. in the soil, such as are obtained from a chemical analysis may easily be misleading. On easily pervious soils, for example light sandy loams, even with low analytical figures the plant food substances for a number of crops will still be more than adequate whereas on heavy clay even with high figures from the analysis, it is by no means certain that the plants will not suffer from both lack of water and lack of food substances. On very sandy soil also there may even be a lack of water and lack of food in spite of high figures from the analysis, since such a soil can hold but little water and a slight drought is very quickly felt. Especially is this so if after a first period of abundant water supply a sharp drought occurs and the crop is taken by surprise, as it were, for in the beginning with a relatively small and shallow root system it had been adjusted to abundant soil moisture.

From this point of view[170] let us now glance at the deposits of ash from the Merapi and the Kloet which are fresh or as yet hardly touched by weathering.

Relating to the Merapi, Tollenaar[171] gives good details. The high, steeper slopes have soils full of stones (volcanic bombs). These soils lie mostly within the forest reserve. Unless whole portions come downwards as lahars, or new eruptions again cover the whole landscape in a new dress of ash and stone (see Fig. 226, page 640) they can gradually weather to good, forest soil rich in air and moisture. Lower down the slopes there is a smaller proportion of ash which has landed directly out of the air. Consequently this ash contains less stone, more sand, and also more fine dust. This is the condition on the ridges and other convex parts of the terrain. In the valleys and ravines lahars and spates have rushed down filling up rather than excavating those concave portions. The best known is the Woro terrain, which is coarse, sandy and full of smaller and larger stones. The Woro river has carried on the very fine sand and silt and has deposited them on lower stretches. Such a lahar sand river has built up a very odd bed (see Fig. 228, page 641, also Fig. 227, page 640).

The whole of the bed lies several meters above the surrounding landscape. Along each side of the channel there are small, not high, little dikes (natural levees). During low water a shallow stream flows along each side of the bed while in the middle is a slightly rounded sand bank. The cross section is like that of a road on a dike. The Kali Konto river, after it has left the mountain ravine and has come out into the low lands, flowing north-northwestwards from the Kloet, shows the same profile.

It is obvious that such a river is a continuous threat to the surrounding land, for after each heavy rain in the upper drainage basin there is the danger of spates overflowing, or breaking through the dikes. When this happens the cultivated fields which are lower than the stream bed are covered over by sand. Both the Woro and the Konto are notorious for this. As

170. These "questions of fertility" have been beautifully worked out in a communication by F. Sekera, Die Anpassung d. Düngerwirtschaft an die Wasserversorgung d. Pfl., in: Die Phosphorsäure 3 (1933), pp. 1-63.

171. D. Tollenaar, Bijdr. kenn, agrogeol. grondtypen Vorstenl. tab. gebied, Meded. 73. Proefst. Vorstenl. Tabak (1932) with beautiful photographs!

Photo by E. C. J. Mohr

Fig. 226. Western slope of the Merapi, Kedoe. Edge of the lahar from the Blongkeng ravine. Paddy killed not by covering with sand, but by warm, acid water. In the background at the right trees singed by the incandescent volcanic cloud (ladoe).

Photo by L. P. de Bussy

Fig. 227. K. Loesa river, a tributary of the Woro, Soerakarta. The bed has been changed into a dike, through overflowing and man's help. Time and again the sand bank in the middle has been dug out and the excavated sand used to build up the banks into small dikes, between which nature has again raised the bed.

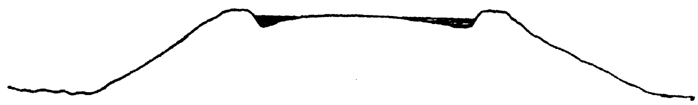

Fig. 228. Profile across the channel of the Woro River, page 639.

a protection a certain tract of land (the "Woro triangle") has been reserved to catch and retain such floods of sand and gravel, so that there will be less danger of other, good agricultural lands being ruined.

In the lower, flatter region at the foot of the Merapi, lying especially southeast from this cone mountain, but also south-southeast and east, Tollenaar mapped the different kinds of soils and in so doing he has differentiated the following soil types:

A. Recent andesitic deposits from the Merapi (western tobacco region). They are very juvenile, and are without developed or weathered profiles.[172] Subdivision of the soils within this type are according to the texture of the surface soil and the height of the ground water table, from the standpoint of agricultural requirements.

The young ash is readily cemented together to form layers of tuff, padas or wadas (cf. in this connection pages 143, 144 and Frontispiece A). As a result of this padas formation (see Fig. 229, page 642) in the surface soil the weathering can proceed in another direction, namely, toward amphibian or subaqueous conditions. This is however not always the case.

B. The old crater wall of the Merapi, lying to the east and southeast, called "Geger idjoe" (= green wall) because it has been overgrown by forest, has, at least for the last few centuries prevented the caving off and sliding down of fresh ejecta toward the southeast. Thus below this old crater wall, fine ash could only have reached the ground directly from the air and from the glowing volcanic clouds (ladoes). These aerial deposits have thus far weathered to dry, brown andesitic dust soils, the first stage on the road to brown lixivium. They may be compared with the so-called "tarapan" soils of East Java and the "andir" lands of Cheribon.

Lower, on flatter terrain, in so far as they are not covered over by the above-mentioned fine deposits from the air, there occur two different, somewhat older soil types.

(a) On higher convex portions, such as ridges, lies a still quite juvenile "andesitic laterite soil," with inadequate water holding capacity so that the vegetation, such as tobacco, often suffers from leak of water.

(b) In the concave, lowest parts, with a high ground water level the "andesitic tuff gray earth" a heavy clay cracking extensively has developed. While lime concretions are certainly not typical for this gray tuff earth, yet here and there they do occur in it. The pH of fresh Merapi ash, as it falls from the air, is about 8.5, thus it is strongly alkaline. Lahar mud can be much more acid (pH = 4.5), because of much sulfuric acid in the water from the environs of the crater. But mud flows with low pH are a phenomenon much more temporary and local. For in itself the ash certainly has an alkaline reaction.

Both types lie on padas which is usually not deep below the surface and, according to Tollenaar, have without any doubt originated from this padas (in other words, via the padas stage).

The entire picture sketched by Tollenaar agrees fully with the conceptions given above (pages 144-172). Also Tollenaar has suggested that the tuff gray earth has perhaps originated from finer material than the brownish red lixivium.

He records further that on "marly tuffs" soils occur which in many respects are closely similar. He gives, among others, the following analytical data (see

172. The Russian school says of such soil "that as a whole it is still not a soil." Nevertheless here tobacco, sugar cane, rice, etc., grow very well on this soil!

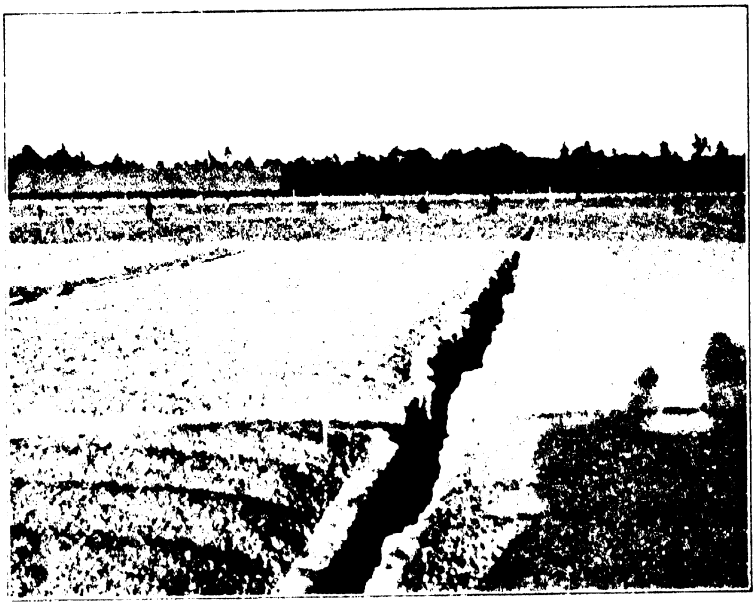

Photo by L. P. de Bussy

Fig. 229. Tobacco plantation in the Principalities. The padas, the cemented or tuff layer, reached in digging the drains, has been taken out and used for walling up the sides of the ditches. Soil is a juvenile Merapi ash, a rich, fine sandy ash loam soil.

Table 135) of two samples of soil on the same rock taken at a distance of only a few meters from each other.

Tollenaar does differentiate the "tuff gray earths" and the "lime or marl black earths" from each other in that the first named is somewhat less heavy (degree of heaviness[173] 8-9, as contrasted with the last named which is always 10). Yet he did not succeed any better than I can in giving a conclusive explanation as to why in one spot the weathering runs in the direction of red earth and in another spot, under apparently practically identical external conditions, black earth develops from approximately the same parent material. Therefore it is to be regretted that besides the above valuable analytical data there could not have been added total analyses of the two kinds of soils investigated as well as of the "rock," the tuffaceous parent material. Mechanical analyses, as well as mineralogical and chemical analyses of the fractions also might perhaps have thrown some unexpected light upon the problem.

c. Along the northern foot of the Southern Mountains there are tuff gray earths which have originated from the "light colored, layered, quite acid (analyses are lacking), trachytic to dacitic tuff, the lowest part of which consists mostly of quite fine gravel material, covered over with coarser, sandier tuff."[174] White[175] considered these tuffs to be "trachytic to liparitic." However that may be, this tuff certainly does not possess much dark, iron-rich minerals and it is certain

173. Determination according to Atterberg, adapted to the Netherland Indies by: G. Booberg, Arch. Suikerind. in N. I. No. 40 (1928), p. 1030. O. Arrhenius, Arch. Suikerind. in N. I, No. 5 (1928), pp. 208, 209.

174. Tollenaar, l. c., p. 23.

175. J. Th. White, Versl. 4e Verg. Vereen. Proefst. Pers. Djocja (1923), p. 82; also Jaarv. Topogr. Dienst in Ned.-Indië (1923), p. 128 (1924).

Table 135

COMPARISON OF A CALCAREOUS BLACK EARTH WITH A RED LIXIVIUM SOIL

	"Rantjaminjak" ("Calcareous black earth")	"Laterite soil" (actually a red lixivium)
Acidity, degree of, pH	7.6	5.7
Exchange capacity	98.1	34.0
H	2.5	12.0
Bases	95.6	22.0
Ca	69.0	13.4
Degree of Saturation with lime	70%	39%
CaO (soluble in HCl)	1.772	0.378
(citrate soluble)	1.184	0.364
P_2O_5 (HCl soluble)	0.009	0.015
(citrate soluble)	0.004	0.002

that these tuffs weather to tuff gray earths containing a considerable proportion of quartz grains. From where these Tertiary, acid[176] tuffs could have come has, incidentally, not yet been determined. It does not appear to be impossible that their origin must be sought for south of the present day Lawoe cone, but with reference to this neither Verbeek and Fennema[177] nor Taverne[178] give sufficient light. In Table 115 page 560 is an analysis of a "pale" tuff coming from the Goenoeng Bangak or Bangkak, south-southeast from the Lawoe. (See the profile in Fig. 230, page 644). It is true that this tuff is no longer entirely fresh (H_2O + is more than 4%), but the Ca content, which usually rapidly decreases early in the weathering process is still more than 5% CaO. The very low content of Fe and Mg is astonishing. From this tuff at an elevation of about 120 m. there has developed a quite typical gray earth, the black Madioen clay (see Fig. 37, page 171) with all forms of $CaCO_3$ concretions.

Travelling around through the districts of Soerakarta and Madioen, we cannot escape from the impression that in the place the Lawoe now stands, or better, the Koekoesan or Djogolarangan, once, possibly in Pliocene time, volcanic activity had commenced with an enormous eruption of iron-poor, silicious, relatively acid ejecta, of dacitic to liparitic nature. That later the eruption of more basic magma, with less gas, had broken out in that locality and had built up the Lawoe as well as also other volcanoes along the northern edge of the Southern Mountains and even had reached the surface in smaller mountains, north from the Lawoe. This basic, andesitic to basaltic magma formed more lava streams and larger and smaller bombs, therefore remaining much closer around the point of eruption, so that these basic ejecta only partly covered over the pale tuffs.

In this way is explained the great extent of black earths in the plains and on gently rolling hilly land of southern Soerakarta, northeastern Soerakarta, and Madioen (see Figs. 34-42, pp. 167-173).

Already long ago the hypothesis[179] that in an earlier time, namely in the last part of the Tertiary and the beginning of the Quaternary, the Solo River flowed out at Ngawi; not toward the north through the marl ridge there, but eastwards via the present bed of the Kali Djeroan and afterwards that of the Kali Widas, so that the Solo River united with the Brantas at the elevation of Lengkong. Lahar streams coming from the Wilis in the south, and from the north from the Pandan, formed a dam between Saradan and Wilangan, which cut the river off. The Solo river must then have formed

176. Possibly acid as long as no analyses are made available.
177. Verbeek and Fennema, Geol. beschr. enz. (1896), pp. 247, 317.
178. N. J. M. Taverne, Vulkanol. Meded. No. 7 (1926), p. 117.
179. Cf.: Verbeek and Fennema: pp. 238, 251.

Photo by E. C. J. Mohr

Fig. 230. Region of the Redjosari sugar mill, near the village of Poepoes, Madioen. Soil profile exposed by a fresh excavation. On the older deposits the "fossil soil" already weathered to a dirty white clay (a) lies newer, pale ash, hardened to tuff (b) on the upper surface weathered to black earth (c). Granular calcium carbonate concretions in (c) at the left above; threads in (b) in the center. An analysis of (b) has been made.

a lake. And so, because of the nature of the relief of the hinterland, the districts of Madioen and Soerakarta, and since the average discharge of the Solo river[180] is 268 m.^{3}/sec., which amounts to 8.10^9 m.^{3} per year, in 3 to 4 years the water must have completely submerged an area of about 2,000 km.^{2}, that is, the present day area of these districts below the 100 m. contour line. Around the edges the submergence was of course only shallow, but at the deepest spots about 50 m. deep.

If the lowest point in the marl ridge which was cut down into in the north was about 100 m. high,[181] then the lake must have overflowed, gradually cutting the

180. See: Versl. Comm. v. Advies nopens Werk i/d Solovallei (1900), p. 8. Average outflow, Nov.-Apr.: 440 m.^{3} and for May-October.: 92 m.^{3}. The amount of the runoff at the time of the cutting-off catastrophe is of course unknown.

181. On p. 250 of the above-mentioned book Verbeek says: "It is clear that with heavy eruptions of Wilis and Lawoe, the Madioen river and also the Solo river as a consequence of the bursting out of Merapi, Merababoe and Lawoe, must have carried away colossal quantities of ash and sand with water mixed to a sludge, which repeatedly flowed over the Tertiary series of hills.... It does not seem to me improbable that the thin tuff layer, which covered marls of Madioen to 100 m. and even 150 m. above the plain (150 to 200 m. above the sea) should be ascribed to overflows of the Solo and Madioen rivers, after heavy volcanic eruptions."

threshold and the new river bed through the marl ridge down to the present day elevation, so that the draining of the lake must have taken a very much longer time than its filling up. This presumption is, however, based upon the fact that the northern marl ridge at the time of the heavy eruptions must have been at an appreciably lower elevation above the sea[182] than now. It is quite conceivable that the supposed fresh water lake never did have this extension over the Madioen plain and the plain of Solo to the present day 100 m. contour line From that view point it appears now by no means so plausible as I formerly believed,[183] and as some even yet believe, that the formation of the black Madioen clay or tuff gray earth must be the result of a previous marsh stage toward the end of the shrinking of the large lake. This now seems to be quite erroneous, for at many places this soil type lies higher than the lake level ever could have stood--it occurs even higher than 150 m. above sea level. For that matter here and there the tuff gray earth occurs even a hundred meters higher. Consequently the formation of this soil type cannot be explained by the hypothesis that it was once a lake bottom soil, then swamp, and finally dry.

But this does not mean that the soil has been placed into the group of soils formed by subaerial weathering--quite the contrary! We must accept that the parent material is very impervious to water (and air). On relatively flat terrains in the rainy season it has lain continuously soaking wet, while the reaction of the unaerated soil moisture was clearly alkaline, and this always hindered a proper crumbling and entrance of air. Under such conditions the typical clay minerals which came into existence belonged to the montmorillonite group, already discussed on pages 526-527 above. These minerals are the ones to which one is inclined to ascribe the high plasticity and stickiness, the strong swelling and shrinking power, and the great power of absorption which characterize these soil types.

Meanwhile there is still another possibility which may be mentioned: If the elevation of the land 100 to 200 m. higher above the sea, of which there is mention in the above quotation from Rutten's lectures, should also apply to these stretches, then that would signify that the sea formerly covered the high lying plains of Madioen and Solo perhaps 100 m. deep. Consequently the tuffs formed during that time would for the greater part be marine tuffs. But since no marine fossils have ever been found in these tuffs, one must either give up this hypothesis, or else assume that the elevation of the land, at least to just above the level of the sea, must have taken place before the great eruptions of fine ejectas, which have now hardened to the pale tuffs. But in this case the sea could not have played any role in the beginning stages of the formation of the black earth.

If a beginning stage of swamp were necessary for the formation of this black soil the swamp water could not have been a peaty, acid-reacting water which might cause the weathering to proceed in that direction. In that case not only all the bases Ca, Mg, K, and Na would have been quickly leached out, but also the iron. Below are some analyses (see Table 136, page 646) which it is true, are far from complete but, since there is a lack of better, are worth recording here.

* * * * *

The analyses (3) and (4) are by Marr, while analyses (1) and (2) have not been credited to any certain researcher.[184]

Apparently soils (1) and (2) have

182. L. Rutten, Voordr. Geol. N. O. Indië, (1927), p. 130, says: "....the surface of the hilly land is clearly an elevated peneplain. And....this raising up must have been very recent geologically for Pliocene layers in the center of the hills, yes, apparently the same layers of the Trinil complex, are still clearly folded." The "vertical elevation of the entire region amounts from 100 to 200 m."

183. E. C. J. Mohr, Tropical soil forming processes and the development of tropical soils, with particular reference to Java and Sumatra (translated by Robert L. Pendleton, Peiping, 1933), p. 81.

184. See: Result. chem onderz rietgr. Java-Meded. Pr. J. S. I. (1926), No. 20, Archief J. S. I. (1926), p. 834; also: Th. Marr, Over padasvorming, Arch. J. S. Ind. (1907), p. 52 ff.

Table 136

ANALYSES OF "TUFF BLACK EARTH" AND RELATED SOILS

	(1)	(2)	(3)	(4)	(5)
SiO_2	57.27	58.02	57.95	54.74	57.92
TiO_2	n.d.*	n.d.	n.d.	n.d.	0.69
Al_2O_3	19.98	19.82	20.39	19.94	18.14
Fe_2O_3	6.44	6.68	8.12	10.33	5.21 } 7.07
FeO	n.d.	n.d.	n.d.	n.d.	1.65
Mn_3O_4 (MnO)	n.d.	n.d.	0.47 (-)	0.18 (-)	- (0.06)
MgO	2.22	2.00	3.59	2.79	1.24
CaO	3.66	3.12	3.57	6.00	5.29
Na_2O	1.28	1.33	n.d.	n.d.	3.53
K_2O	0.53	0.51	n.d.	n.d.	1.58
H_2O + ...	5.90	6.38	5.44	5.11	4.31
Humus (CO_2)	2.83 (-)	2.10 (-)	0.50 (-)	1.21 (-)	- (tr)
P_2O_5	0.073	0.073	--	--	0.21
S	--	--	--	--	0.21
Ba	--	--	--	--	0.05
Cl	--	--	--	--	0.02
Cr_2O_3..............	--	--	--	--	0.01
Total	100.18	100.06	100.03	100.30	100.12

*. n.d. = not determined

	Elevation above the sea
(1) Tuff black earth--Madioen clay--Soedhono sugar mill-Boelaän village	50 m.
(2) " " " " " " --Tambakromo village	60 m.
(3) Subsoil of "white padas"--Modjopanggoeng sugar mill (Kediri) Simo village	85 m.
(4) "Black clay"--Modjopanggoeng sugar mill--Tandjoengsarie village	120 m.

originated from "Lawoe tuff"; (3) is quite likely "Wilis tuff," from which (4) may be considered to have been formed. Recalculation on the moisture free basis, there is also added here (see Table 115) (5) the analysis of Goenoeng-Bantjak tuff, from Redjosari sugar factory (Madioen), Poepoes village, which is quite in agreement with the four other analyses.

As is evident, these figures do not diverge greatly. If samples had been included which had been leached by swamp water, the content of Fe, Ca, and alkalies would certainly have been much lower.

* * * * *

If you now ask: Are the volcanic products from the <u>Kloet</u>, in comparison with those from the <u>Merapi</u>, exactly the same or are there notable <u>differences</u>? Then first of all we must refer to the analyses (in Tables 22, page 36; and 115 page 560). It is, however, dangerous to make such a comparison on the basis of the meagre data available, because from Merapi, except 8 rock analyses, only one (old and incomplete) ash analysis is available. On the other hand from the Kloet, besides 13 ash analyses, there is only one rock analysis (andesite) from the Gadjah Moengkoer summit and one (basalt) from the Goenoeng Soembing summit. It is apparently correct to ascribe to the Kloet ash a higher content of Fe and Mg and a lower content of K and P than is contained in the Merapi products. But with the Kloet ash we ought also to distinguish between ash which fell close to the crater and that which fell at a great distance from the crater. The dark minerals

Photo by Herrmann

Fig. 231. Lahar field from the Kloet, in Kediri. For the time such soils are of practically no agricultural value.

hypersthene, augite, hornblende, with much Fe, Mg, and Ca, fall relatively very rapidly from the air. Consequently the ash samples from close to the crater have the highest figures for these elements. The fine blown-out glass of the ash which has fallen at great distances is richer in Si as the distance from the crater increases. As to K and P, however, these differences are not so great as those between the Kloet and the Merapi. The Merapi is, if one may put it so, more fertile as to P and K. Apart from all sorts of other factors, it is possible that this is the reason why, although Kediri near the Kloet is a tobacco region, the Principalities and Kedoe closer to Merapi have developed into better tobacco regions.

The Merapi produced more lava, also stones and bombs, and in addition to these, much ash. The Kloet principally produced ash, sand, boulders, bombs (see Figs. 45-48, 50, and 231) and lava. Consequently the Merapi is a steep mountain, while the slopes of the Kloet are much less steep, so that more of it can be planted. On the Kloet, therefore, are many coffee plantations, while on the Merapi there are only few at similar elevations.

It is unknown whether the Kloet, as well as the Lawoe and probably also the Merababoe and Merapi, and perhaps also the Wilis as has been mentioned above, had begun their volcanic development with SiO_2-richer, pale efflatas, which later were converted into "white tuffs." In any case the many later andesitic and basaltic efflatas have completely covered all the earlier ejecta in the surroundings of these volcanoes. Thus near the Kloet we do not find any "tuff gray earth," nor any black clay. In the plain of Kediri the soil which resembles it the most lies in the most distant northwestern corner, at Ngandjoek, so that it is difficult to identify this soil as derived from a Kloet product. Much more likely the Wilis and the Pandan are responsible for the material, but in connection with the above suggested possibility that the Solo river at that time flowed along in the bed of the present day Kali Widas, the more westerly lying volcanoes may have contributed something.

Table 137

MECHANICAL ANALYSES OF SUGAR PLANTATION SOILS

No.	Sugar Plantation	I 2-1 mm.	II 1-0.5 mm.	III 0.5-0.25 mm.	IV 0.25-0.1 mm.	V 0.1-0.05 mm.	VI 50-20 mu	VII 20-5 mu	VIII 5-2 mu	IX 2-0.5 mu	X less than 0.5 mu	I-III Coarse Sand	V-VI Fine-sand	VII-VIII Silt	IX-X Lutum
4640b	Kentjong (Ked.)	15	30	23	9	4	5	4	6	3	3	68	18	10	6
1200	Ngadiredjo (Ked.)	3	23	32	17	9	9	4	2	2	1	58	35	6	3
4088	Meritjan (Ked.)	0	1	4	5	7	15	19	16	13	20	5	27	35	33
4089	" "	0	1	8	8	4	5	8	19	23	23	9	17	27	46
765	Poerwoasri (Ked.)	0	0	1	6	20	43	21	6	3	2	1	69	27	5
228	Sedati (Soerab.)	0	2	32	28	13	9	6	4	4	3	34	50	10	7
4132	Poppoh (Soerab.)	0	0	0	1	2	5	7	22	31	32	0	8	29	63
1152	Krian (Soerab.)	0	3	25	34	11	8	7	5	4	4	28	53	12	8
1154	" "	0	1	7	21	20	19	11	8	7	6	8	60	19	13
1156	" "	0	2	5	7	12	36	23	8	4	3	7	55	31	7
1156c	" "	1	1	2	2	9	33	25	17	6	4	4	44	42	10
1676	" "	1	4	15	18	8	6	7	9	15	16	20	32	16	31
1728	" "	1	1	4	12	11	7	7	17	20	21	6	30	24	41
1727	" "	0	0	1	2	6	10	13	22	21	25	1	18	35	46
1187	" "	0	0	0	0	1	9	16	16	26	32	0	10	32	58

In the last 35 years few volcanoes have received so much attention from researchers[185] and writers as has the Kloet, most probably because of the eruptions of 1901 and of 1919. In the field of soil science we find all sorts of information, for example, from the point of view of the cultivation of sugar cane, and the encouragement of native agriculture by the Agricultural Extension Service. But it is very difficult to integrate these data systematically, for one agency has studied and analyzed its soil samples from one point of view, while another has analyzed other sets of samples to evaluate entirely different characteristics. Consequently it is useless to try to correlate the reported soil characteristics.

This much, however, is clear: on the Kloet slopes and its broad foot, and also everywhere that lahars, floods and the Brantas have carried the ejecta, colluvia and alluvia of various sorts lie in apparent confusion intermixed with each other in all sorts of combinations. Here and there, quite close to the cone of the Kloet lie alluvial accumulations of silt on and between sand and gravel masses, through which they seriously hinder the water movement in the soil directly upon these masses.[186] On the other hand quite close to the sea, near Porrong, in the center of heavy loams, lie sand and gravel masses which are fresh Kloet material. A few mechanical analyses were taken from a survey of a great number of such analyses[187] of sugar factories in the drainage basin of the Brantas, in a region lying between the Kloet and the far side of the Sidoardjo delta. These data have been collected in Table 137 above.

A number of Kloet soils, from Upper Kediri to close to Sidoardjo, is followed by a series from a sugar plantation in Krian. These constitute a series with a wide range of textures from light, very sandy soils to heavy loams or clay. Most of the soils are largely composed of three fractions (note the underlined numerals). A couple, Nos. 1676 and 1728, appear to show a frequency curve with two peaks. This can come about through a mixing of two deposits, for example, as a result of plowing, but also through weathering, during which the

185. We can here only refer to the geological and vulcanological literature of Verbeek and Fennema, Cool, Houwink, Kemmerling, Stehn, Taverne, and Tromp, among others, and especially to the publications of the vulcanological Service. Many of these publications are illustrated by most excellent photographs.

186. I have dealt with water difficulties in the Kloet soils in the meeting of the Kediri Agricultural Association (22 Nov. 1914). See Pub. Ned.-Ind. Landb. Synd. 7 (1915), pp. 58-62.

187. O. Arrhenius, Phys. eigensch. suikerrietgr. Meded. Proefst. J. S. Ind., No. 5 (1928). Arch. (1928), pp. 195-307.

sand decreases and the finest fractions increase.[188]

Samples Nos. 1200, 228 and 1152 are typical colluvial river deposits[189]; the curves are clearly assymetrical. Numbers 1156 and 1156c might be sediments, or ash deposited from the air but more probably they are only alluvial deposits.

In view of the discussion on page 636 ff. the many hundreds of determinations of phosphorus, soluble in HCl and in citric acid, which have been carried out in the last 40 years and more, can here remain outside of consideration. It may be noted that the larger and largest amounts of P are in the coarse, sandy sediments but even so such soils frequently respond to fertilization with phosphorus.

The younger, volcanic products of the Lawoe and the Wilis are the same pyroxene andesites as were ejected by the Kloet. Those two volcanoes, however, have been extinct a very long time, so that the surface of the slopes covering these volcanoes has undergone an intensive weathering and the soils have reached the stages of brown and brownish red lixivium. Especially on the lower foot slopes of the volcanoes this soil should be thoroughly senile, except that occasionally there is a fall of ash from the neighboring Kloet and Merapi which refreshes and modestly rejuvenates the soil. Also the irrigation water, obtained from the rivers flowing off from these volcanoes and thus coming from higher, still less senile regions, brings with it increasing fertility for the lower regions which have already largely been converted into paddies. The plain of the Madioen as well as the plain of the Kediri are irrigated as thoroughly as possible by modern systems but there is a great difference between these plains. That of Madioen is for the greater part the above already-discussed tuff black earth, while that of Kediri for the greater part, especially on the right bank of the Brantas, consists of fresh deposits of Kloet material. Consequently the best irrigated portions of Madioen seldom produce[190] more than 22 quintals paddy per hectare while the lowest yielding paddies on the Brantas deposits seldom give less than 26 qu./ha. The average difference is a good 9 qu./ha. It is very much a question whether this is due entirely to a difference in content of plant food materials. That the Madioen plain is such a heavy stiff clay and the Kediri soil is such a light sandy loam, is enough to make a difference in water circulation. This is a reason for crop diseases such as mentek, occurring earlier in Madioen than in Kediri.[191]

That the plain of Kediri is not universally such a mixture of all possible kinds of soils but in one portion is predominantly sandy and light, and so too dry, and in another part predominantly loamy and clayey, and often too marshy, was shown by Paerels[192] in a striking way by indicating on a map of Kediri the distribution of certain crops of the native agriculture. It was evident, for example, that in the north-western part of Ngandjoek, which had received but little fresh Kloet material on heavy senile, dark brownish black swamp clay soil, soy beans were the principal crop in the east monsoon, while peanuts were practically not cultivated at all. On the opposite side against the Kloet many peanuts were grown, but never soy beans. In this way it is often possible to read off from such statistical crop maps where coarse grained soils lie, where fine textured ones are to be found, and how the conditions are for the supply of water to the plant.

* * * * *

The reader has doubtless already noted that only very general statements have been made in the preceding pages regarding the volcanic central strip, which

188. Cf. pp. 179-186.
189. Ibid.
190. Detailed figures are, among others, to be found in the repeatedly referred to Landbouwatlas met beschr. (1926).
191. See: Verslagen van den Landbouwvoorlichtingsdienst, and of the Afd. Landbouw.
192. B. H. Paerels, Toep. induct. meth. bij agrol. onderz., Verzam. Verhand. Bodemcongres, No. VII (1916), pp. 65-80.

is the most important agricultural part of Eastern Central Java. As long as a more detailed soil map has not been made, much less published, it would most certainly be premature to go into detail. Numerous have been the researches relating to the fertility, the productive possibility of paddy cultivation (field experiments of the Agricultural Extension Service), and to the cultivation of sugar cane (field experiments and soil research by the experiment stations of Pasoeroean and Jogja). However the results will only be of the most value when suitable soil maps are available. Today that is still not the case.

Once again with reference to the productivity of rice, it may be stated that the yields in the lower, flatter portions of the region here being discussed in the east are roughly about double those in the west.[193] In Soerakarta the production per successful hectare, east of the Solo river, is approximately 17 quintals, in Madioen 20 qu./ha., in Kediri from 25 to 30 qu./ha. averaging about 28, in Djombang 29.5 qu./ha. and in Sidoardjo 30 qu./ha. with maxima of 33 qu./ha. for Krian and 38 qu./ha. for Modjoagoeng. Whoever is interested in any particular locality, may investigate what factors may be important. It might be water supply by the soil to the roots, abundance or scarcity of plant food materials in the soil (phosphorus, especially plays an important role) or some other factor. Higher up on the slopes of Lawoe, the Wilis or the Andjasmoro, growing conditions are not so favorable since the soil is more senile and poorer, or dries out earlier because of the steeper slope of the land. Consequently above the district Madioen with its yield of 20.5 qu./ha. there lies the district Goranggareng with 18 qu./ha., and above that Magetan with 14 qu./ha. where the paddies lie on very stony lahars of the Lawoe (see Fig. 7, page 123), which naturally depresses the production per unit of surface area. Above the Kediri district yielding 30 qu./ha. lies Modjoroto with 26 qu./ha., and above that, on older brownish red Wilis soil is Berbek with 21 qu./ha. From Modjokerto which yields 29 qu./ha. one passes through Modjosari with 24 qu./ha. toward Djaboeng yielding 23 qu./ha. Each of these areas is successively higher and farther from the Brantas plain. Pandakan, lying between the Penanggoenan and the Welirang averages only 19 qu./ha.; the soil here is quite a bit older and lies relatively higher and dry.

With respect to other crops raised in these regions, such as maize, cassava (Manihot utilissima), sweet potatoes, soy beans, tobacco, etc., the available data in the literature[194] are not of such a nature that it is possible to deduce generally applicable conclusions relating to the soils on which the crops were grown.

* * * * *

To the north and to the south from the central volcanic strip which extends across Eastern Central Java lie the Tertiary Mountains with the soils associated with these formations. First we will consider the Southern Mountains, from Jogja to about to the Smeroe. Next we will consider the Northern Marl Ridge, from Semarang to Soerabaja, and then the so-called calcareous ridge to the north of that, and finally the Moeria Mountains with their surroundings.

The Southern Mountains consists of a few quite strongly differentiated parts. The most westerly part, belonging mostly to Jogja, shows in its southerly half, named Goenoeng Sewoe, a typical karst landscape (see Fig. 232, page 651), described in detail by Van Valkenburg and White.[195] We will content ourselves however with a few remarks relating to the soil.

On the limestone, soil can form only from the impurities of the limestone itself, as well as from what in the course of time falls upon it as dust from the air. Since the limestone, like the residues which

193. According to the figures of the frequently referred to Landbouwatlas and Text, Meded. Centr. Kant. Statistiek, No. 33 (1926).

194. For example, in the Verslagen van den Landbouwvoorlichtingsdienst and the Afd. Landbouw. An exception is the already above-cited paper by B. H. Paerels.

195. S. Van Valkenberg and J. Th. White, Enkele aanteeken. omtr. het Zuidergeb. (G. Kidoel), Jaarversl. Top. D. in Ned.-Indië (1923), pp. 127-140 (1924).

Photo by Soil Congress 1916

Fig. 232. A sink hole in the limestone region, cf. G. Sewoe, Jogjakarta. In the foreground are limestone remains of the edge, in the center is the lake now dry, with a red lixivium soil, which is planted to maize. Forests on the limestone have been cut off, the soil is washing into the sink hole.

remain over from it after weathering, is quite pervious--otherwise there could not have developed on this great calcareous reef the numberless dolines (weathering funnels, or sink holes),--the intermittent, leaching type of weathering has resulted in the formation of a brownish red lixivium, which is called <u>limestone red earth</u>, in many respects agreeing with "terra rossa" of other parts of the world. Except the dust particles (volcanic ash, etc.) which have fallen onto it during the land stage, the above mentioned impurities in the limestone have in the course of their deposition been in contact with the sea. Consequently the very first weathering commmences in each case in a pH of about 8.4, i. e., in an alkaline medium. According to what was said on page 526 ff., such a reaction favors the formation of montmorillonite, which not only brings with it stickiness but also plasticity. This terra rossa or limestone red earth is then also obviously heavier and more plastic and has a much lower sticky point than brown earth and brownish red lixivia from eruptive or sedimentary material, which had never been in contact with the sea, and in which the pH can just barely rise above 7, and then only for a very short time.

A century ago the summits of the Goenoeng Sewoe were mostly covered with forest.[196] Now this forest, in part teak, has disappeared and certainly for good,[197] because all the soil from the ridges and summits has been eroded leaving bare rock. The soil has been washed into the sinkholes and in part has been carried down through the drainage tunnels into the

196. According to the description by Junghuhn, Java I, 2e dr. (1851), pp. 342-345. However the lower valleys were even then for the greater part deforested and covered with cogon and <u>Saccharum spontanaeum</u>, in which were scattered many <u>Albizzia stipulata</u> trees.

197. Unless man intentionally and systematically reforests the land.

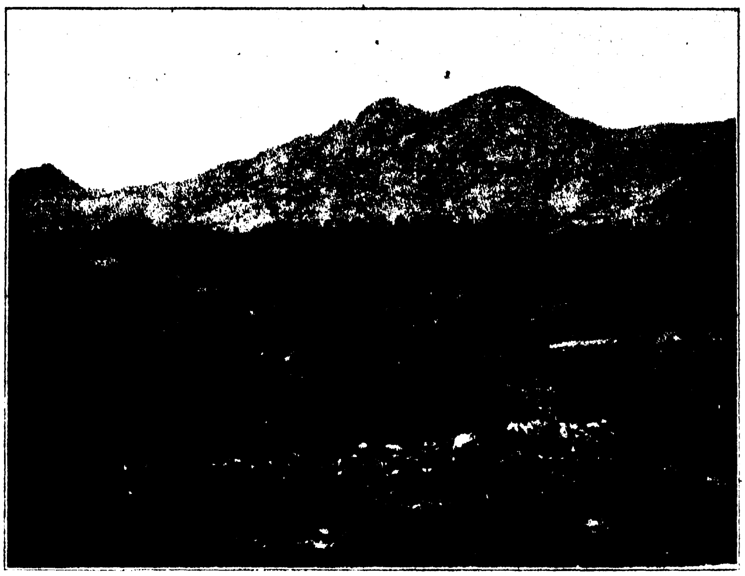

Photo by L. P. de Bussy

Fig. 233. Wonogiri, Soerakarta. Deforested mountains of old volcanic rocks, from which the soil has been eroded off into the low plain, where the villages of the natives are located.

subterranian rivers, and so has vanished toward the sea. Where the outlet of the sink-hole has been stopped up, a pond has formed with the following effects upon the soil: under subaqueous conditions the pH falls, iron migrates, formation of concretions results, and the color of the subsoil becomes more or less flecked and flamed with red. Ultimately at some other point the water in the pond finds a new course through the limestone, the pond becomes dry (see Fig. 232, page 651), and through reoxidation and being all mixed up and ultimately completely inverted as a result of deep cracking, the soil becomes entirely red. The iron concretions remain unaltered.

More to the north the limestone, because of increasing clay content, grades into a marl. The soil is no longer red earth, but a gray to black marl soil. On the already above-mentioned (pages 639-642) pale, fine tuff lies tuff gray earth,[198] but on the andesitic and basaltic conglomerates and tuffs red lixivium has developed. Since from the soil science standpoint this entire region has already been studied by the Institute of Soil Science at Buitenzorg in far more detail than we can within the scope of this book, if the reader wishes to learn more of this region he is referred to the results of those studies which, in the course of time, it is hoped will be published.

* * * * *

South of the Lawoe the karst region becomes smaller, and beyond Patjitan, near Panggoel, disappears entirely. To the north of this point, thus south of the Lawoe, and on further east, to south of the Wilis, approximately from Wonogiri to beyond Trenggalek is an extensive <u>mountainous land of volcanic origin</u> (classified by Verbeek as m_1). It is very rough country.

198. This may be observed along the road between Tamansari (Madioen) and Trenggalek (Kediri). Compare Fig. 235, p. 654.

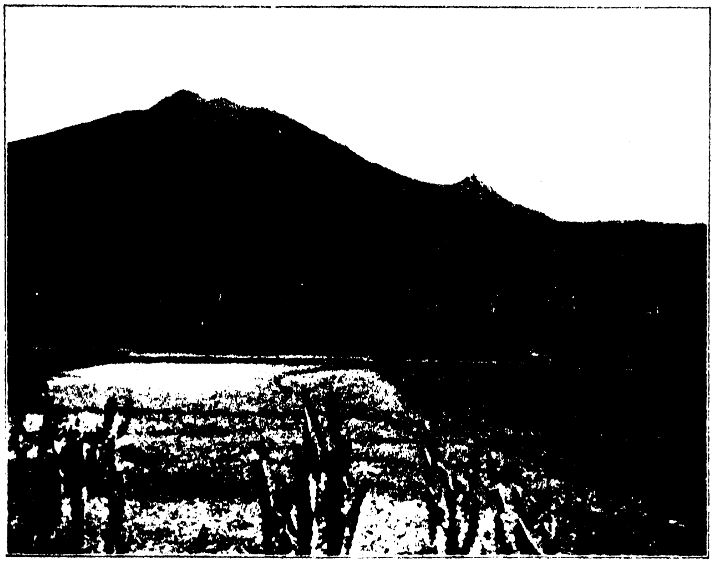

Photo by E. C. J. Mohr

Fig. 234. Near Sampit, Madioen. Completely deforested andesite mountain. As a result of erosion of the soil bare rocks are appearing at the surface. Soil of the slope is a grayish brown lixivium, in the plain a very dry black earth. On the slopes terraces have been made to try and hold the soil for the cultivation of maize, which does not do very well.

The forest which once without doubt covered this entire region has been deplorably ruined, and as a result of kaiñgining the senile brownish red soil has declined seriously in production. Erosion has done the rest. Many mountains and ridges show a picture similar to those in Figs. 233-235. In so far as it is held back at all, all the good soil that is left lies on the valley floors. Most times however, these are alarmingly small or are lacking entirely. Only in a few places can be found a small or larger valley plain and in these are also the principal settlements of the inhabitants (see Fig. 233, page 652).

With respect to the deforested mountain slopes the reader may ask whether these vegetation-less and soil-less stony lands will really ever again be covered by soil. The answer must be something as follows: These slopes, by themselves, do not have any soil, there is nothing in which to plant anything, and the soil which through disintegration and weathering continually forms from the rock cannot accumulate, for it is immediately washed off. The only possibility thus seems to be planting permanent trees, thus reforestation, to be begun in or just above the plain. As along the upper edge of the forested strip more and more eroded soil accumulates and is held securely, then there should be more planting, gradually working up the slope, until after a long time the top is reached. But that will require a very long time! Consequently the Government must take a long view of the matter and adhere to a consistent policy throughout many years. If by such measures there could only be achieved a much more regular runoff of the rivers, which come out of such mountains this would curb the flood damage and so increase the yield of paddy. Then there would be ample justification for a long continued program of reforestation. What rational forest management would also accomplish in providing

Photo by E. C. J. Mohr

Fig. 235. Koekoesan Mt., west from Trenggalek, Kediri. A beautiful columnar laccolith of hornblende andesite, formed by the weathering away of the softer layers. In the foreground black earth with maize stubble and red pepper plants.

abundant supplies of timber and fuel would be a second and continuously invaluable advantage.

* * * * *

In the course of time the Bening and Tjampoerdarat swamp lying to the south of Toeloengagoeng will certainly be drained and cultivated. To the east of this swamp the geological map of Verbeek and Fennema indicates an extensive limestone mountain (m_3) which extends on to the south of the Smeroe. This also is a very broad statement, for subsequently at a number of points, where non-calcareous windows show through the limestone cover, there has been found volcanic conglomerate upon which has developed a red lixivium. Also only in a few places have sink holes formed and there are only a few instances of the disappearance of rivers. Possibly after the revision of the geological map this region will be shown to be of a very different nature from that stated above. In the course of a number of trips southwards from Malang, personally I obtained the impression that the limestone, which indeed does play an important role in this region, is often strongly tuffaceous, full of fine volcanic sand. The soil originating from it and developed under forest is of a peculiar roe or leather-brown color, and heavier than that from volcanic parent material without calcium carbonate. In profiles which extend downward to the yellowish white or sometimes salmon-colored, flecked limestone little differentiation into horizons is to be seen. At most the surface soil is darker because of humus. But in the coffee gardens of the Malang region, much, very much of this humus layer has been lost. Twenty-five years ago a coffee planter[199] gave the following graphic description of this soil: "....a color history. From the hilltops of the estate which I am at present managing there is an extensive and beautiful view over the plantations

199. G. J. Zuyderhoff, Over het Behoud van de Bouwkruin, Publ. Ned.-Ind. Lb. Syndt., IV (1912), p. 625.

of the Southern Mountains.--If one had stood on one of these summits 18 to 20 years before (1892-1894) he then would have seen round about him the fresh green of the young coffee plantations alternating with the black spots of the new clearings. .... But if we now (1912) stand on one of these same vantage points, conspicuous gaps will be noted in the green just where the earlier black spots were, marking newly made clearings. At the present time these gaps show all shades of yellow, brown and even white and gray, in the immediate vicinity of red, from scarlet to poppy red. If this change of color had not occurred, how very different would now be the value of many plantations. What a calamity is here recorded!"

These words of a clear-sighted planter are unfortunately also applicable to all too many other regions of the Netherlands Indies. Fortunately, however, to this it can be replied that in a continually increasing degree during the last twenty-five years, progress has been made toward healing and prevention of such fatal destruction of soil capital. Terrassing, green manures, and cover crops are now being used.

Meanwhile it was a great blessing for the Southern Mountains of Malang that many coffee gardens which had become unproductive could be replaced by Hevea. And we should not leave unmentioned that in this region under the Government's control is the Blitar reservation, a 35,000 hectare "natural timber forest." It is true that but 18,000 h. is real natural forest, for the rest is still not completely forested, or has been deforested. However, through planting and rejuvenation the stand is being brought into better condition.

* * * * *

Northerly from the volcanic part of Eastern Central Java lies the largest continuous body of Tertiary formations, marls and limestones. It is roughly enclosed by the lines connecting Semarang, Toentang, Djombang, and Soerabaja. Within this region lie the four mountains of eruptive rocks, namely, the Moeriah, the Goenoeng Lasem and the Boetak, as well as the Pandan, which will afterwards be dealt with separately.

Two principal ridges run through this region. The southern one usually for short called the marl ridge, and the northern or limestone ridge. The latter consists principally of limestone, but there are also marls and even claystones and sandstones in it. Moreover, what is of still more significance is that the limestones contain quantities of coarse and fine quartz sands which have come from somewhere to the north,[200] mixed with tourmaline, zircon, and sometimes andalusite--a sand such as the reader may recall is found in great quantities in Bangka and Billiton. Under a leaching type of weathering the calcium carbonate disappears from such limestone and leaves behind mostly quartz sand.

It was in the Neogene age that rivers brought down from the north the quartz sand which as shore formations or in the shallow sea, was deposited with the calcareous remains of marine organisms to form sandy limestone. The finer material, which in itself would be called loam and clay, was carried further southwards into the sea and there sank with shells of lime-collecting organisms, especially Foraminifera, to build up thick sediments which later hardened to marls, and which at present are found as the marl ridge to the south of the limestone ridge. This marl ridge is not purely of one sort of rock--nature never follows entirely one or another distinct line. Consequently in this marl ridge there are limestones, and extremely fine loam slates and claystones. Whenever, however, coarser, easily determinable mineral sand occurs in this formation it is predominantly effusive: plagioclase, hornblende and on the southern side augite, hypersthene and magnetite--thus of andesitic origin. This sand could have been brought in by water--by the rivers and sea currents, from the more southerly lying

200. See: E. C. J. Mohr, Ergebn. mech. Anal. trop. Böden., Bull. Dépt. Agric. Ind. Néerl., No. XLVII (Buitenzorg: 1911), pp. 48-51 and: L. Rutten, Herkomst mater. neog. gest. Java, Versl. Kon. Akad. Wet. Amst. XXXIV, 2 (1925), pp. 685-708. Cf. also what was said about this above on p. 595.

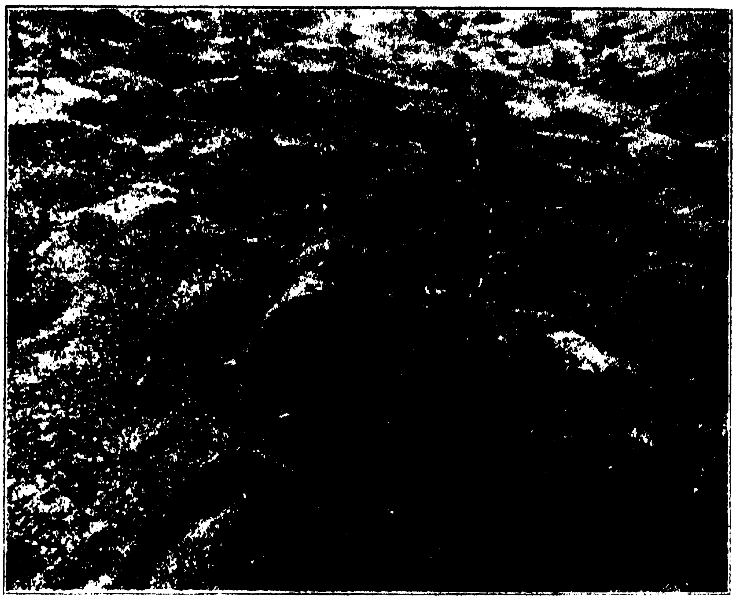

Photo by the Forest Experiment Station

Fig. 236. Goendih, Semarang. A miserable stand of cassava (Manihot utilissima), in a marl soil robbed first by surface erosion, granulated now through drying and shrinking. Beginning of gully erosion.

volcanoes, but also it could have come from the air, as ash. If, as is often the case, these minerals are found in or between the rocks of the marl ridge, then they must have come from eruptions synchronous with the deposition of the marine strata in the Tertiary. If they are found especially in the soil above, lying over the rocks, then the probability is great that they have originated from more recent eruptions. More detailed, local investigations, will perhaps ultimately supply data relating to the above stated (page 643-645) hypothesis. This hypothesis is that in the prehistory of the Lawoe there had been great eruptions of relatively acid, iron-poor magma, such that the accompanying ash, as well as the glass, was made up predominantly of plagioclase, and some hornblende. It practically never contained augite nor hypersthene.

It is clear that the weathering of the marl ridge rocks could not have given rise to sandy soils. The lightest could be only a loam, with most of the textures a heavy loam or clay loam. For the formation of red earth or a bright brown lixivium the iron content is also too small. Moreover the permeability of the residue which remains behind after the leaching out of the calcium carbonate must always, even from the beginning, have been too low. The climate over the whole region is quite uniform and really quite dry (see the map, Fig. 6). In the west it is at most somewhat more moist; in the east it can be called somewhat drier. Consequently it is understandable that on the marls, as a rule, a gray to black soil forms with an undesirable yellow marl subsoil which is heavy, and poor in air. The iron present is inclined toward the formation of concretions, becoming hail ore. Where the soil is able to accumulate to a considerable depth at a slight depth, from 1/4 to slightly more than one meter, the $CaCO_3$ collects into lime concretions. This fits in with the description on pages 177-178.

On the limestone ridge, on the contrary, sandy soils can indeed develop here and there. Quartz sand however was not the only substance which "contaminated"

Photo by J. Klay

Fig. 237. Wilaloeng diversion works, Demak, Semarang. Down stream from the flood diversion works the dike has slumped out, showing these allochthonous marl soils to be very soft and very plastic. The portion of the dike which flowed into the river has been washed away.

the lime deposits. As a result there has come into existence a loamy sand or sandy loam, or clayey sand, or sandy clay or sandy red lixivium, depending upon the source and nature of the accessory substances, or whether earlier or later more or less volcanic ash was spread over the ridge. In general the color of the soil on this ridge is on the red side, many times a pale red. If sufficient humus is present the surface soil is then reddish gray.

Although the ridges are but a couple of hundred meters high and in spite of the fact that the greater part of the surface is occupied by forest, the erosion in these stretches is extremely rapid. But this forest is teak forest, which stands leafless during the dry season of several months, so that the soil can dry out to a considerable extent. Then the monsoon wind whisks some of the soil away from the higher slopes and carries it off, depositing it in the valleys and plains. And when the rains do break, they fall not only on the loose sandy soils and wash them off, but the heavy marl clay soils also erode. In the dry season not only does the heavy, black to yellowish gray clay crack and slake down (see Fig. 236, page 656) to an extremely fine powder, a dust, which the wind can carry about, but in the rainy season this marine clay swells up to a plastic, movable mass with a marked tendency to slump down (see pages 131 and 139 and Fig. 10, page 133). Hence, the steep slopes settle down as a whole, and only very gently sloping land can remain in position (see Fig. 237 above). If the mass which slides down is saturated with bases, especially with lime, and thus consists of flocculated clay, and if it does not happen to land in a plain where it can remain stable but lands directly into the river, then the soil mass disintegrates easily and very rapidly to a porridge which the flowing water carries off with it (see Fig. 225, page 631). This is the cause of the pale gray tint of the rivers coming out of such regions, when the water is

transporting such enormous quantities of material as suspended silt. Regarding this Den Berger and Weber[201] give striking figures. The Loesi, for example, during the west monsoon has an average silt content of 2,133 grams per cubic meter (g./m.^{3}). In the east monsoon this figure is 716 g./m.^{3}. These quantities are enormous when compared with the quantities carried by the Tjiliwong, above Buitenzorg, where the upper drainage basin is free from marls and is entirely of volcanic nature. During the west monsoon, in spite of the heavy rainfall, only 101 g./m.^{3} is carried, during the east monsoon 30 g./m.^{3}, and for the year 60 g./m.^{3}, i.e. but 1/20th to 1/25th of the amount of silt carried by the Loesi. For the Tjilowoeng the maximum measured in a spate was 1,638 g./m.^{3}, while for the Loesi it was 14,518 g./m.^{3} and for the Tjojo, a tributary of the Loesi, it was about 44,000 g./m.^{3}.[202]

On the limestone ridge the red to reddish soil, with more or less quartz sand, offers more resistance against landslides; slopes and river banks remain standing much steeper. But heavy showers wash the finer clay down through the sand into the deeper soil and in another way this is also an unwelcome process, for there comes about a marked division into different horizons, of which the uppermost is richer in sand and is very pervious, while the horizon just below is richer in clay and is more difficultly pervious. But fortunately for Java, in this island I have never seen this phenomenon so strongly developed as with the soil types of the Lafayette series in the Southeastern United States: In that region there was a horizon of from 1/3 to 2/3 m. of almost pure, washed-out pale reddish sand on a subsoil of strong red, orange to yellowish flamed lixivium. To be able to plant a crop on land of that kind, one must first for the greater part dig out and carry away the sandy horizon. The results were less good, but it was also indeed practicable to mix up the soil homogeneously to a depth of a meter, or to bury the surface 1/3 m. with the deeper lying 2/3 m. from below. But for the purpose of establishing teak culture such an extensive working of the soil on the limestone ridge of East Central Java can never be profitably carried out. Not even if maize or rice were planted in place of teak, because through intermittent leaching this limestone red earth or terra rossa had been impoverished and decalcified until it is no longer fertile enough to make this worth while.

N. Beumee-Nieuwland[203] was the first to notice the fact that in the teak forests a very pervious horizon is underlain directly by a poorly pervious one. This condition is as a rule connected with a lower fertility. The author pointed out the unfavorable water conditions which thus must exist in the soil, and how the second horizon must certainly suffer from a deficiency of air. The author might well have added how this evil is to be combatted. On such soil types as these, which have a tendency toward differentiating themselves into horizons in this manner, I should always avoid the complete cutting off of the natural forest cover, for it is clear that the washing down of the clay deeper into the profile during heavy rains must occur especially when the surface is exposed.

* * * * *

In so far as the rapidly flowing flood water does not carry the suspended matter farther toward the sea, the consequence of the heavy erosion of these Tertiary hilly ridges one finds in smaller and larger <u>plains</u>. Especially the marl silt which has a grain diameter from 1/2 mu. to not more than 50 mu, either practically never settles out or is a sediment which practically all falls approximately betwee the mentioned limits of grain size and thus can be called "heavy loam," a type of alluvial soil which is rather frequently

201. L. G. Den Berger and F. W. Weber, Water- en slibonderz. rivieren Java, Meded. Alg. Proefst. Lb. No. 1 (1919).
202. In this connection also compare the important studies by L. Rutten, Over denudatiesnelheid op Java, Versl. K. A. v. W., Wisen Nat. Afd. 26, I (1917-18), pp. 921-930.
203. N. Beumee-Nieuwland, Onderz. v. djatiboschgronden op Java, Meded. Proefst. Boschw., No. 8 (1922), pp. 27-37.

found in the plain of Demak as a result of the heavy floods in the Kali Loesi and the Kali Serang. From the sandy limestone ridge however, two sorts of deposits originate. The weathering soil on that ridge has been derived from an originally sandy sediment, a calcareous sand (Foraminifera shells, etc.), mixed with grains of quartz, feldspar, hornblende, etc. The calcareous sand dissolves and disappears while the quartz sand remains behind unaltered. The other minerals gradually weather to fine clay, becoming a red lixivium. The quartz sand has a grain size from 20 mu to sometimes as large as 500 mu. The clay is principally smaller than 2 mu. Thus the frequency curve[204] has two summits, with a minimum of the grain size 5 to 20 mu. If a weathered soil of this nature washed off into a river, then it is obvious that the sand settles out sooner than the clay, so that in one place a sand bank or sand ridge is deposited, and elsewhere a clay soil.

In the Kening valley this phenomenon of differentiation is very clear. Even the native farmer marks the difference and has given each of the soil types distinct names. He calls the pale sandy soil "tanah brandjangan"[205]; and the clay soil he calls "tanah batan" (river clay). That the tanah brandjangan is very poor and thus must be fertilized, is also quite obvious to the farmer, for sometimes he takes hundreds of quintals of the heavy clay (tanah batan) which he spreads out over the pale sandy soil. Especially if the site from which the clay has been taken is an old, abandoned cemetery and as a consequence has a high content of P, the success of this treatment is indeed astonishing. But even so the effects are not by far so marked as with fertilizers carrying P. For example, Affourtit records the following[206] experiment with paddy:

	quintals paddy per hectare
Unfertilized	0.57
Fertilized with tanah batan	5.23
" " nitrogen	0.69
" " phosphorus	20.--
" " P and N	25.--

Indeed a striking effect of fertilizing with superphosphate (87 kg. single super per hectare). After the P is added, the shortage of N can be remedied by adding N carriers, but not before. Also with tobacco striking results have been obtained:[207]

	quintals wet tobacco leaf per net ha.
Unfertilized	15
Fertilized with farmyard manure	35
" " ammonium sulfate (A/S)	39
" " A/S and single superphosphate	59
" " A/S, Single superphosphate and potassium sulphate	64

That such marked differences have been obtained with the use of the different fertilizer treatments indicates clearly that this fine sandy clay soil must be very good physically, but only hopelessly poor chemically, being most deficient in P, but also in N, and finally also in K. Moreover it is still also a question whether without fertilizing even enough Ca and Mg are present, while perhaps still other constituents are likewise on the scant side.

A piece of good fortune may be mentioned about these two ridges, the "lime ridge" and the "marl ridge," which for annual crops are of such low value. They appear to be very well suited for teak, although I must at once add that there are a number of places where, after cutting of a good, old teak forest young teak plantings do not seem to succeed at all

204. Cf.: E. C. J. Mohr, Ergebn. mechan. Anal. trop. Böden, Bull. Dépt. Agric. Ind. Néerl. XLVII (1911), pp. 58-61.

205. Because of the similarity of the color with that of the Javanese sky lark "brandjangan" (*Mirafra Javanica*).

206. K. J. Affourtit, in: Jaarversl. Lb. Voorl. dienst (1915), p. 64 (1917).

207. *Idem, idem* (1916), p. 81 (1918).

brilliantly. The reason for this may be explained as follows: the old trees live on what they can take up from great depths with an extensive root system while the young trees must get along on what the surface soil can and will now supply to their very limited root system. During the long life of the old trees, say approximately a century, this surface soil can have been and will probably have been considerably altered. Repeated burning of the fallen leaves, grazing of cattle on the young shoots, and intensive erosion are certainly reasons enough for the surface soil of today to no longer have the quality of the surface soil of 100 years ago. And unless sweeping and extensive precautionary measures are taken, which cost money, the young plantings do not do so well and the former fertility is never regained again. And whether such measures can be adopted becomes a problem in arithmetic which goes beyond the scope of this book.

Fortunately alterations in the soil, in so far as my experience goes, have always been of great interest to the officials of the Forest Service. The results of this interest have been a number of important papers, for the greater part published in "Tectona," while others have appeared as special publications of the Forest Experiment Station. Somewhere or other in this book most of these papers have already been referred to. The rest of this literature, which is too extensive to discuss here in detail, may be referred to with a word of introduction.

The influences which I have mentioned as having an effect upon the surface soil of the teak forest are illustrated, if we consider the cultivation of tobacco in the smaller plains and also on the low flat ridges during a long period of time. In particular in Rembang, about a hundred years ago, much tobacco of excellent quality was raised; tobacco is still grown there, but the quality has seriously declined. Humus content, water capacity, and content of plant nutrient substances must by this time have become unquestionably very much less favorable and if the prospects of the Rembang tobacco had not been already so very poor in 1863, young Nienhuys would perhaps never have taken the big chance he did and might not have shifted the cultivation of tobacco to Deli in Sumatra.

* * * * *

Now something about the eruptive rocks in the Tertiary region. Along the northern coast, east from Rembang, in a row from the north to the south[208] stand the volcanic peaks Lasem, Poetjak and Boetak. All three of these volcanoes have Tertiary limestone and marl strata lying upon their slopes; thus these mountains must be older than the Tertiary. They are made up of hornblende andesite. The soil on this rock is a reddish brown lixivium, conceivably quite senile and not over moderately fertile. These little volcanoes have had no influence upon the soils of the marine Tertiary formation.

The Goenoeng Pandan and the Goenoeng Lawang, lying on the boundary of Madioen, Ngandjoek and Bodjonegoro also form a similar old volcanic complex. The rock which they have erupted is in part also hornblende andesite. It is in part, however, pyroxene andesite and even contains olivine, and thus is presumably more basic (analyses are lacking). Although fragments of these rocks have been found enclosed in the marl matrix rocks, there has not really been any modification of the composition of the marls. These volcanoes have perhaps at times erupted ash, but that must have been before the marls and the limestone had been formed. Thus from a soil science standpoint these volcanoes remain unimportant windows in the Neogene covering.

But we cannot say this of the last volcano to be mentioned, which is the Goenoeng Moeriah. While none of the "babies" above-mentioned are higher than 1,000 m. above sea level, the Moeriah reaches up to about 1,600 m. and if its peak had not caved in, it would certainly have extended up to 3,000 m.[209]

The mountain is quite old, no longer showing any volcanic activity.

208. Cf. Verbeek and Fennema, l. c., pp. 218-221.
209. See: Verbeek and Fennema, l. c., pp. 255-261.

Since on the surface it has been built up especially out of loose ejecta it is quite deeply weathered to red lixivium. Below that, several meters deep, under the lixivium are to be found horizons which must be considered eluvial as to the bases Ca, Na, and in part also K and Mg, that is to say these bases have been for the greater part washed out of those horizons. But as to Si, the quantity leaching out downwards is still less than the amount of Si coming in and being deposited from horizons lying higher in the profile. Thus with reference to Si these deeper horizons are illuvial. The material of these layers has a strong base-binding power and results in the formation of trass,[210] Moeriah trass. In all older volcanic deposits such a trass horizon is to be found. Above it lie layers from which not alone the bases but also the colloidal Si have been leached out. While deeper down are the layers from which the bases have not yet been completely leached out and into which the colloidal Si has as yet been only partially deposited.

The Moeriah is further differentiated from all the volcanoes which we have thus far considered in Java, because of the occurrence of the mineral leucite as a constituent of its rocks. In Table 24, p. 38, are recorded a number of analyses in which the relatively high K content of the magma of this volcano is evident. At the same time it is of importance that the large, peculiar green pyroxenes (aegirien augites) and also the amphibole crystals and even the flakes of mica visible under the microscope all show larger or smaller inclusions of apatite. This explains the relatively high P content of the Moeriah rocks, rising to above 1%. The K content is from 4.5-6.5%; Ca, Mg, and Fe in the ferrous form are present in adequate quantity to give rise to a soil which will be generally fertile as long as it is not senile. But most of the soils are senile since, as already mentioned, the volcano is now quite old. It has thus been through the stage of being completely covered by heavy tropical high forest, notwithstanding that there is a marked difference in the rainfall between the east side and the west side. In Japara in the east monsoon a strong dry season on the lee side of the mountain prevails, while on the windward side to the southeast of the peak, it is always raining.

Under the tropical high forest the erosion of the soil was limited. But as the deforestation advanced further and further, the erosion of the humous surface soil naturally became more and more serious. At present the only forest still remaining is on and around the highest parts. And in so far as the land is not being permanently cultivated there are considerable areas of cogonal and parang (a cogonal in which stand some low scattering fire-resistant trees). And here we see the crops which are indicated by nature (see Fig. 238). Where there is much irrigation water and the supply is certain, paddy and sugar cane are grown. In the west (with a severe east monsoon) where there is no irrigation kapok grows, while in the east (with more uniformly distributed rainfall throughout the year) all sorts of fruit trees; Tajoe is certainly a fruit growing region. In the north and northwest, where the dry east monsoon is not a hindrance, rubber is cultivated. But important annual crops are never grown. The rule also applies here that on more or less senile red soils tree cultures are especially suitable: kapok, rubber, and fruit are all tree crops.

* * * * *

Finally now we must turn our attention to the large rivers of the northern half of Eastern Central Java.

The Solo river, coming out of the mountains south from the Lawoe, begins its course carrying a load of silt of volcanic nature and much, very fine, white tuff material, especially glassy dust and feldspar dust. Flowing through the plain of Soerakarta, it receives from the left much Merapi ash, etc.; while from the right, from the Lawoe, it receives less. North from Solo more and more silt from the marl ridge comes in from the left (see Fig. 239, page 662). First mixed with detritus from pale

210. Cf.: E. C. J. Mohr, Over het voorkomen van tras in Ned.-Indië, Ber. Afd. Hand. Mus. Kol. Inst. 4, (1920), also in: De Ind. Merc. (10 Dec. 1920).

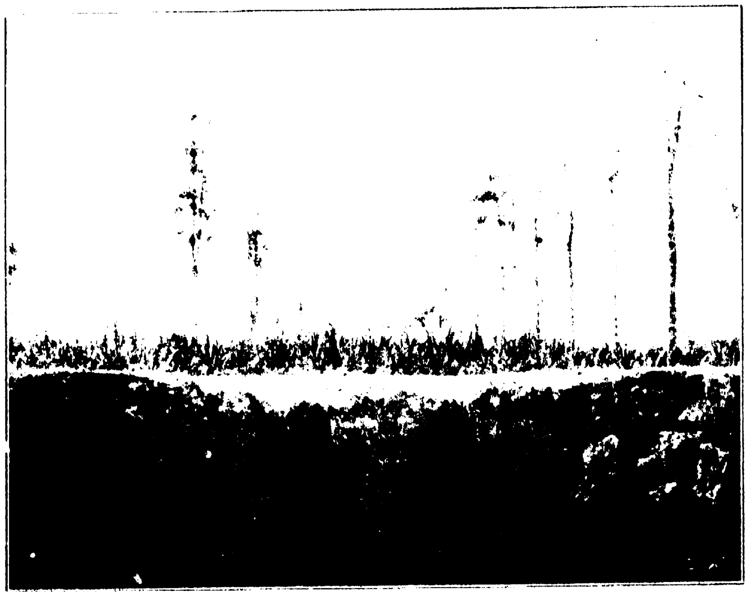

Photo by E. C. J. Mohr

Fig. 238. Eastern foot of Mt. Moeriah, Semarang. Allochthonous red lixivium with a layer of cobble stones at 3 meters depth. Sugar cultivation on a terrain with many kapok trees.

Photo by E. C. J. Mohr

Fig. 239. Region of marls rich in tuff, northwest of Kalioso, Soerakarta. In the foreground on the summit a crown of Foraminiferal limestone.

Photo by L. P. de Bussy

Fig. 240. Modjokerto, Soerabaja. Brantas loam deposits. Soil preparation for the cultivation of sugar cane, done by hand.

Photo by L. P. de Bussy

Fig. 241. Modjokerto, Soerabaja. The same Brantas loam deposit as shown in Fig. 240. Soil preparation for the planting of sugar cane. The previous day the furrows were opened by the motor plow, and already the soil is beginning to show cracks.

Photo by E. C. J. Mohr

Fig. 242. In the north of the plain of Demak, Semarang. Cotton plants about 1/3 m. high. Harvesting in progress. Soil an allochthonous marl material of the K. Serang river, plus some red lixivium coming from the Moeriah.

tuffs, thereafter with more and more calcareous sand and silt, as well as clay. Just beyond Ngawi still more marl silt comes in and the Madioen river also brings in with it quite a good deal of clay and a little fresh volcanic silt. Taking it all together, when the river, after breaking through the marl ridge, begins to build up the plain it is transporting four principal sorts of sediment. (1) Sand, volcanic, basic calcareous feldspar, augite, hypersthene, and hematite; principally from the Merapi, but also from the Merbaboe and the Lawoe, even from the Wilis. (2) Calcareous sand, eroded out Foraminifera from the marl ridge. (3) Dust, volcanic, glass-rich silt, from the mountains south from the Lawoe, plus that from the region north and northeast of the Merbaboe, as well as that brought along by the Madioen river. (4) Clay, coming along with (3). In addition some (4) eroded off from the black earth, most of which comes from the marls. And along with that there is much fine calcareous silt, also from the marl region.

The deposits are thus of two sorts: Sandy colluvium, juvenile, very fertile and certainly not heavy textured; and alluvium, heavy clay or loam, much less juvenile. Unfortunately much of the heavier valuable sand is by degrees moved along the bed of the river on into the sea. When during spates the land is flooded, it receives a covering of heavy clay containing relatively little sand. As a consequence the fertility of the "Solo valley" is but moderate, and is not to be compared with that of the Brantas delta. The latter, where the favorable physical characteristics of the juvenile Brantas deposits are more clearly demonstrated by the working of the soil which can be afforded by and is necessary for sugar cultivation on it (see Figs. 240, 241, page 663), has a large number of sugar factories. In the Solo valley, on the contrary, there is not a single sugar mill. The rice yield in the Solo valley, calculated as the average of 16 districts along the river, from Randoeblatoeng to Sidajoe, amounts to about 15.5 quintals per hectare.[211] The three most easterly districts of Karangbinangoen,

211. According to the figures from III in the repeatedly cited Landbouwatlas, Centr. Kant. Statist. Meded. No. 33 (1926).

Bengawandjero and Sidajoe still profit the most from juvenile volcanic sand and from the sea. Their average is 22 quintals paddy per hectare, so that for the remaining districts, excluding these 3, the average is not even as much as 14 qu./ha. Along the Brantas the comparable figures for 10 districts, from Blitar to Kertosono, average 27.5 qu./ha., and for 11 districts from Djombang to the sea the average is 29.2 qu./ha.; roughly double the paddy yield of the Solo valley!

Along the Loesi and the Serang rivers, which, like the Solo, are heavily charged with marl silt, the average paddy yield from Djepon to Manggar also comes to about 14 qu./ha., while the average of the plain of Demak, for the greater part built up out of such silt, is about 19 qu./ha. For the entire Loesi, from Blora to the sea, the average is about 15.5 qu./ha. One could wish for no more beautiful agreement between the Loesi and Solo rivers.

Meanwhile, keeping to broad generalizations, there appears to exist a striking correlation between the productivity of the soil for lowland paddy and the density of the population. From the figures of the previously mentioned Agricultural Atlas and those of the Census of 1930 the following approximate table[212] (see Table 138) has been drawn up.

Table 138

RICE YIELDS IN DISTRICTS ALONG THE LARGER RIVERS OF EAST JAVA

Brantas	Paddy qu./ha.	Inhabitants per km.^{2}	Solo River	Paddy qu./ha.	Inhabitants per km.^{2}	Loesi and Serang Rivers	Paddy qu./ha.	Inhabitants per km.^{2}
In Kediri	27.5	470	Ngawi → Lamongan	13.8	266	Djepon → Manggar	14.2	232
Djombang → sea	29.1	610	Karangbinangoen → sea	21.8	417	Oendakan → sea	19.1	306
These together	28.0	532	These together	15.3	285	These together	16.2	247

The plain of Demak deserves passing attention because of the cotton cultivation which is found here, even though this crop does not do especially well. The growth of this crop is here possible, because:

(1) The farmer is as good as certain of a dry season of three months for the harvest. (2) The soil has a high water capacity, coupled with a slow water movement, so that the cotton plant, even during a drought, can still obtain just enough moisture to be able to continue alive and ripen the bolls. And (3), the heavy soil and the rotation of cotton with paddy apparently helps keep down the insects more than it encourages them. See Fig. 242, opposite.

* * * * *

EAST JAVA

Under this heading there are left to be dealt with the two residencies of Pasoeroean and Besoeki, the "eastern corner" of Java in the geographical sense. This should not be confused with the Government of East Java in the political sense. In connection with what was stated on page 632 regarding the boundary of Eastern Central Java, we can say that the region remaining to be considered is roughly that part of Java to the east of the line connecting Soerabaja and Malang.

* * * * *

Three great volcanic complexes dominate eastern Java: The Tenggar mountains, the Ijang mountains, and the Idjen mountains. In comparison with these, the Lamongan, the Goenoeng Ringgit and the

212. Closely scrutinized, these figures cannot be completely correlated. The annual figures of 1916-1920 on the one hand and of 1930 on the other do not completely agree and moreover the boundaries of various districts have been altered. However, these points do not greatly modify the general picture.

Baloeran volcanoes are of very modest dimensions. Of the Southern Mountains the part belonging to Malang has already been dealt with under Eastern Central Java so that there is left for consideration that portion of the mountainous region to the south of the Idjen complex. There also remains the Blambangan peninsula. With the treatment of the northern coastal plains, the Malang plain, the Loemadjang-Djember plain and the south Banjoewangi plain the principal geographical regions will have been covered. If one wishes to obtain at a glance an idea of the various relationships then the General Topographic Map, scale of 1:250,000 showing the principal roads, should be studied.

Of the three great volcanic complexes the Ijang mountain has long been extinct. Since of the three it has been visited and studied the least by geologists and other scientists, as to geographical and petrographical details we know the least about this complex. The two other complexes, on the contrary, since they still possess active volcanoes, have been given much more attention by these researchers. These include the Tenggar mountains,[213] the Bromo and the Smeroe, and the Idjen mountains, the Raoen and the Merapi with Kawah Idjen. Viewed from the standpoint of soil science, this extra attention is very welcome in order to understand the great significance of the recent efflatas of these active volcanoes for the soils of the slopes and the lowlands contiguous with these volcanoes.

Geologically and petrographically we know nothing more about the Ijang mountains than what Verbeek and Fennema[214] have recorded about them. There they state in the conclusion: "In general the Hijang rocks are much richer in olivine than the products of the Idjen." Analyses of these rocks, which for the greater part are basaltic, have not yet been carried out, but that they are on the basic side is quite likely. But, just preceding that passage on page 104 we read: "By far the greatest part of the Hijang consists of loose products, ash, sand and stones, some of which attain colossal dimensions." In general, however, it is just those (intermediate) andesites which in the Netherlands Indies are violently erupted in such great quantity, while the true basalts with low SiO_2 content are more apt to form lava streams. This is thus another reason for believing that the Ijang rocks are intermediate, with amounts of SiO_2 between 55 and 60%. In short, to determine this point a number of analyses are essential. We especially need samples from the north, and especially from the neighborhood of the small Loeroes volcano of leucitic rock (more about this later).

The Tengger mountain has many times been an object of study. But in so far, however, as the questions concern more especially vulcanological researches, we will not discuss them further, and the reader who is interested in that aspect should consult the literature.[215] Regarding the important questions as to what kinds of rocks, mineralogically, did the Tengger mountain produce and how and when did these come to the surface, we may now briefly answer: especially basalt and less andesite; for the greater part blasted out as efflata (see Figs. 11, 243), while less magma flowed out as lava streams (see Fig. 32). As to the time, presumably it was during the whole of the Quaternary, and for the Bromo and the Smeroe down to the present day[216] (see Fig. 244, page 667).

Already in the first part of this book (page 31) there have been recorded a few analyses of Tengger rocks. In Table 115 (page 560) are a few more. We need here add only this remark, that a single

213. One can, as we have done here, apply the name "Tengger mountains" in an inclusive sense, so that the Bromo complex, the Ajek-ajek, and the Smeroe will be included. The topographic map, however, uses "Tengger Mts." only for the Bromo complex and thus there is lacking a designation for the broader whole. The same is true of the "Idjen mountains." According to the topographic map the Raoen falls outside of this designation. But if we follow this what are we to call the whole group of mountains which one rides around when taking the road which passes through Sitoebondo, Bondowoso, Djember, Banjoewangi and Assembagoes?

214. Verbeek and Fennema, l. c., pp. 98-106.

215. For example, de Vulkanol. Meded. Nos. 4 and 7 (with abundant references to additional literature).

216. See: Verbeek and Fennema, l. c., pp. 119-129.

Photo by E. C. J. Mohr

Fig. 243. Near Tosari, Pasoeroaen. This road cut shows shoving of complexes of layers of varying palo and darker ash from the Tengger volcano. All is juvenil Bromo ash tuff, without lava.

Photo by Th. Wurth

Fig. 244. Pasoeroean. North slope of the Smeroe at the time of its last periodical activity. This view shows the variable equilibrium between the forest growth which is striving to grow farther up the slopes, and ash which is coming downwards as ash rains and washed off the summit by the rain.

sample (shoshonite) has a relatively high K content 2.67%. But most of the others show just as low figures for K. The quantity of P varies widely. Ca, Mg, and ferrous Fe are in general high. All this is in agreement with the occurrence of dark brown to black glass in the rapidly cooled ash, scoriae, and pumice stone. And compatible with the presence of the minerals, Ca-rich plagioclase, olivine, augite and hypersthene, this material weathers easily.

If during the last 50,000 years the Smeroe and the Bromo had been dormant, given the above characteristics of the rocks, at present the whole complex would certainly be entirely covered with a deep brown to brownish red lixivium, loose because of the high content of Fe, and the higher above sea level one went, the more humous the soil would be. Now man has indeed taken care that, especially in the lower portions, the forest has been destroyed and much surface soil eroded off. But the craters have again and again caused a rejuvenation of the soil which continually tends to become senile. Consequently this soil has never been definitely senile, for it is a brownish red lixivium with an incorporation of fresh ash which covers the flanks of the Tengger mountain. On the Smeroe, which is a still younger volcano than the Bromo complex, even the third weathering stage has never been attained. One finds only juvenile grayish brown, grayish gray and light gray soils, in but the second and/or only the first stages of weathering. The higher portion of the Bromo complex shows a similar picture, with all road cuts exposing to view the successive layers of coarser and finer, lighter and darker colored ash (see Fig. 243, page 667).

The Idjen complex[217] includes older and younger volcanoes. There are those such as the Goenoeng Djampit, the G. Ranti and the G. Soeket which, although younger than the original G. Idjen, of which now only a bit of the crater wall (the G. Kendang) is left. Still all are so old that they "must be classified with the extinct volcanoes." Nor are various secondary volcanoes, occurring within the caldera, doing anything more (see Fig. 243, page 667). But the Kawah Idjen, belonging to the Merapi, still shows some life, at present in particular through intensive solfatara activity, as a result of which the water of the crater lake becomes highly acid, as much as around 0.95 N. free HCl and H_2SO_4 (pH = 0.02).[218] The silicifying action of such "water" on rocks falls outside the conception of soil and soil formation, consequently we will not consider it here.

And then in the same way that the Smeroe is annexed to the Tengger mountain, there is annexed to the Idjen mountain the great, active Raoen, which has erupted a number of lava streams. But through its mighty ash eruptions and lahars it has had much more influence upon the landscape, especially toward the west, southwest, and south. The last important ash eruption was that of May to July, 1913.[219]

According to the description by Brouwer,[220] the ash of this eruption was very dark colored, almost black. Dark glass and much magnetite are the principal causes of this. The relatively low amounts of Mg and very small amounts of K are additional factors. The analyses (Table 115, page 560) are unfortunately incomplete: Ti, P, and Mn were not determined.

Kemmerling summarized as follows the results of the earlier and his own petrographical researches, not alone relating to the Raoen, but to the entire Idjen complex:[221] "Almost all Idjen volcanoes, including the primary G. Idjen, have erupted basaltic as well as andesitic rocks. The petrographical and chemical composition of the older Idjen rocks hardly differs at all from those of the newer." From the fact that the chemical composition of the different rocks diverges less than the mineralogical and the petrographical it appears,

217. For details, see the beautiful monograph: Het Idjen-Hoogland. Uitgeg. d. d. Kon. Nat. Verg. Batavia, II: G. L. L. Kemmerling, Geologie en Geomorphologie van den Idjen.

218. In the same monograph II: H. W. Woudstra, Anal. merkw. water-soorten Idjen, pp. 150, 155.

219. A. J. Ultee, Meded. over Raoen-ash, Meded. Besoekisch Proefst., 7 (1913), pp. 11-15. H. A. Brouwer, De Raoeng en Zijn jongste eruptie. Natuurk. Tidjschr. Ned.-Indië, 73 (1914), pp. 84-97.

220. Brouwer, l. c., pp. 94-95.

221. Kemmerling, l. c., pp. 135-136.

Photo by Bley

Fig. 245. The Idjen plateau, covered with grasses and groups of trees, a park landscape in the eastern corner of Java. In the distance is Mt. Kendeng, in the left part of which is visible the cleft through which the Banjoepoetih flows off. At the right Mt. Ringgih.

however, that a small variation in the chemical composition strongly modifies the conditions of crystallization. If there be silicic acid, it concentrates itself more strongly in the first crystals, the phenocrysts. If there be somewhat less silicic acid, the phenocrysts are the SiO_2-poor or SiO_2-free minerals, and the silicic acid concentrates itself more in the glass remaining over. So there originates a series of rocks from the more basic, glass-rich olivine--basalts to the amphibole-hypersthene andesites. But the basalts still form the principal portion, both of the lava streams and of the ashes. A basalt lava stream from the Merapi flowed eastwards into the Bali strait (Batoe Dodol, see Table 115 page 560).

To the foregoing also belong the extinct Baloeran, and the active Lamongan, both basaltic volcanoes. The Lamongan has this peculiarity, that from a presumably extensive source of magma in the depths of the earth, the magma rose not only through the principal crater pipe, but also through a number of smaller cracks around the center. And because of the especially large amounts of gas the magma was blown out. In this way the "blow holes," "dry lakes" or "filled lakes" which were subsequently filled with water originated. When the magma was blown out or forced out with somewhat less gas, then the "boccas" or adventitious volcanoes originated, built up mainly out of black pumice stone, scoriae and ash. Seldom did any lava flow out to contribute to these cones.

* * * * *

From all the above volcanic material taken together a number of important soil types have developed, important with respect to area as well as with respect to economic utilization. With regard to Besoeki, Van der Veen[222] has written a valuable survey.

222. R. van der Veen, Bodemtypen i. h. Ressort V. h. Besoekisch Proef-station, Meded. Bes. Pr. st. 51 (1934).

Photo by S. J. Wijmenga

Fig. 246. Ijang plateau, in the eastern corner of Java. Vegetation principally of grasses and tjemara (Podocarpus). Soil here and there somewhat peaty (elevation more than 2,500 meters).

As was to be expected, on the old Ijang in the lower stretches there are red to reddish brown lixivium soils. Higher up the red disappears and the soil becomes more grayish yellowish brown. Still higher, above 700 to 800 m. the color remains the same, but there commences the "mountain granulation," the formation of "pseudo-sand."

Actually the surface soil never becomes entirely red. It is the subsoil which is red. The surface soil is always darker, having been tinted more a gray by humus from the forest vegetation and by showers of quite dark colored ash. But lower down on the slopes the forest was first destroyed by man and the soil put into cultivation. That gave an opportunity for strong soil erosion of the locser surface soil to commence, so that the subsoil was exposed at the surface; before that it was all a good red. Higher up this took place later. Both the weathering went on more slowly and the cultivation with the erosion commenced later.

There are thus two reasons why erosion must be prevented on the slopes of the Ijang: (1) For the preservation of the old forest humus, which is valuable here, as everywhere else in the Archipelago. (2) For the preservation of the young ash from the Raoen and Lamongen, so that it may raise the fertility, both chemically as well as physically. This applies particularly to the perviousness and water and air capacity of the soil. The same applies to all other older volcanoes in the neighborhood of active volcanoes now scattering ash. In this way the Kawi and Ardjoeno profit from the Bromo, the Smeroe and the Kloet, and in the Lampongs of Sumatra the Ratai profits from the Krakatau, etc.

That the Ijang mountain has not been cultivated higher than is now the case is, except on the forest reservations, certainly also to be ascribed to the fact that higher up this complex of volcanoes is so terribly rough. There are steep walled ravines of quite 800 to 1,000 m. depth. It is quite comprehensible that no one plants anything there. There are thus three zones: the lowest, occupied by the native inhabitants, with paddy and all sorts of secondary crops. The next one

where the European planters produce coffee and rubber. Still higher up is the third zone, the forest. Way up at the top, above approximately 2,200 m. there is tjemara (Podocarpus) forest or open grass flats (see Fig. 246). Above here on flats covered with grass, a sort of peat forms. At first it is of a pale color. The soil under that will most probably (samples have not yet been studied) have an acid reaction, so that in addition to the usual bases iron will also be leached out and a pale lixivium will be formed. The name "pallescivium" was established,[223] for this soil, but the term, however, has not yet found general acceptance.

As to the soil, that on the older Bromo complex of the Tengger mountain must be clearly differentiated from that on the Smeroe. It is true that the Bromo and the Smeroe are both still active ash-erupting volcanoes, but at the present time the ash from the Bromo is small in amount and for the greater part remains within the great caldera. That of the Smeroe, however, has been spread over all the slopes of this volcano (see Fig. 244) and even on the land beyond to the west and east from it, in part through the air, but much more via the lahars (mud flows), here called besoeks.

Hence it is clear that the slopes of the northerly Tengger, in the narrower sense, are somewhat more weathered than those of the Smeroe. Since those of the latter are in weathering stages 1 to 2, then those of the former are in stages 2 to 3 but not further than that. Besides the many and enormous lahars which have flowed down toward the north and northeast and of which still large masses of great boulders remain, there have also been small eruptions of ash which have extended out beyond the area of the caldera, and have made their contribution to the rejuvenation of the soil. Consequently the slopes abovementioned are on the way toward brown to reddish brown lixivium, but so diluted with more or less pale gray that at many places they now show this color. The true yellowish brown or brownish yellow soil, such as one finds in the mountainous districts with continuously much rain, we do not find here, because since there is an annually recurring dry season of a few months the weathering is an intermittent leaching type (see map, Fig. 6).

On the slopes of the Smeroe the weathering stages of the ash vary from 0 at the top, to 1 to 2 below. In other words the soil is as juvenile as is that on the Kloet. On these slopes the battle, so to say, between vulcanism and vegetation (see Fig. 244) may be seen very clearly. If vulcanism gets the upper hand, then the fresh ash wins some ground, and the timber line is forced downward. While if the ash eruptions cease for a time, then the vegetation wins and the timber line moves upwards. If from now on the volcano should cease erupting, then without doubt the vegetation would climb up, though it would progress at continuously slower rates, until it would finally reach the top at about 3,600 m. It is of course true that at the top there would be no tall forest. Just as on the Tengger, in the strict sense of the term, and on the Idjen Plateau, the tjemara (Podocarpus) forest would predominate. Above about 2,000 m. (see Fig. 247, page 672) and especially still higher, above 3,000 m. there would be more scrub, dwarf forest, as is the case on other mountains of these elevations. However, there never would be a zone permanently without any vegetation.[224]

That more plantations lie around the Smeroe, in spite of the fact that the soil on its slopes is really somewhat too fresh[225] for ideal agricultural purposes, and that the slopes of the Bromo complex in that respect are further along, is apparently entirely a question of water.

The Smeroe soil consists predominantly of fresh, quite coarse, volcanic sand, besides much gravel and large boulders, as may be seen in the ravines where the rivers flow through these deposits (see

223. E. C. J. Mohr, Tropical soil forming processes, with special reference to Java and Sumatra (translated by Robert L. Pendleton), Peiking, 1933, p. 93.

224. Cf.: C. G. G. J. Van Steenis, Hfdst. Botanie in: A. H. Colijn, Naar de eeuwige sneeuw van tropsch Nederland (Amsterdam, 1937), pp. 268-275, and: Van Steenis, Bull. Jard. Bot. Bzg, S. III, Vol. VIII, p. 329.

225. Cf.: E. C. J. Mohr, Typ. verschillen t. Smeroe-en Zuid. geb. gronden, Publ. Ned.-Ind. Lb. Synd., 10 (1918), p. 949.

Photo by Bley

Fig. 247. Tjemara (Podocarpus) forest, Idjen plateau, in the eastern corner of Java. (Cf. p. 682.)

Fig. 248. Valley of the K. Manding creek, on the east-southeast slope of the G. Smeroe, east Java. Steep ravine bank in lahar material, very fertile and therefore completely covered with vegetation in spite of being practically vertical.

Fig. 248, page 672). Consequently these soils have only a low water capacity. Water available for the plants is thus quickly used up by the crop plants (coffee, rubber). But seeing that the southern and southeastern slopes of the Smeroe, also in the east monsoon always have much rain, as shown in the map (Fig. 6).(as well as may be learned from the rainfall data of the Observatory at Batavia) the soil seldom has an opportunity to dry out, even for a short time, so there is little possibility that the plant growth will suffer. If the soil be completely protected against erosion by natural forest or forestation there also gradually develops a brown lixivium which, the higher one goes, the darker colored becomes the surface humous layer. Between 400 and 1,000 m. as well as sometimes even lower and also still higher, there are numerous plantations, originally exclusively of coffee, later more and more of rubber, but also with plantings of tea. With reference to the peak of the Smeroe these plantations are concentrated especially in the south-southwestern sector, because more toward the west the annual dry season during the east monsoon becomes more intense, and because more toward the southeast the rainfall becomes too heavy, causing lahars (besoeks). It is worth noting that Deuss[226] also called attention to the small maximum water supplying capacity of the Smeroe soils, which can be improved only by much humus.

For information regarding the soil on the slopes of Idjen mountain and the Idjen plateau the reader is again referred to the previously-cited publication by Van der Veen. The oldest soil type is found on the oldest formation, the Kendeng ridge, especially in the northwest and so the least influenced by the younger eruptions. On the northwest slopes Van der Veen[227] differentiated three distinct soil types, one above the other. An uppermost belt, above 1,200 to 1,300 m. consisting of the pseudo-sand or brownish yellow mountain lixivium with a dark gray surface soil and a tolerably pale subsoil. "Quite suddenly at about 1,300 m. this sandy soil changes into a yellowish brown clay." And below that, at about 900 m. the soil changes irregularly into a red, strongly cracking quite senile mountain clay." Thus a red lixivium coming into existence because of intermittent weathering. During a visit to the Pantjoer plantation, one of the few on Java which still successfully grows Coffee arabica, I made the following note: the plantings above about 1,200 m. were entirely free from the elsewhere so much feared leaf disease; going lower than 1,200 m. the disease was noted only occasionally. Farther down more was present, but even as low as to 900 to 800 m. it was not troublesome. The coffee was able to carry on and yield a crop, although not as well as higher up. Even below 800 m. there were indeed a few gardens, but these were in a precarious condition. 700 m. is the lower limit of the plots planted to this crop. It is indeed astonishing how closely the limits of the leaf disease, thus the possibilities of cultivation, approximate the boundaries of the soil types. It may be stated this way: In a climate like that of Pantjoer, arabica coffee can be safely planted on pseudo-sand soil (above 1,300 mm.), but on brownish yellow mountain lixivium (between 900 and 1,300 m.) only if great care always be taken. Below 900 m. it is better not to plant at all on red lixivium. This quite nicely summarizes the results of experience.

Planting other crops on these red lands of the northerly slopes is almost never done. The lower one goes, the fiercer the dry season is in the east monsoon. Since the period from May to and including November is, during many years, practically rainless and the soil holds only a limited quantity of moisture which it can place at the disposal of the vegetation, only those crops should be planted which stand in the field during the rainy season of at most 4 to 5 months. The conditions are about the same as on the northern slopes of the Tengger.

The northeastern quadrant of this mountain is indeed the very driest. In this region there is neither a single plantation, nor a single village. This region is covered by thin forest which, the lower one goes, the more it grades into savanna with here and there a group of trees (see Figs.

226. J. J. B. Deuss, Theegronden van Java en Sum., Meded. Theeproefst. LXXXIX (1924), p. 51.
227. Van der Veen, l. c., p. 25.

Photo by Bley

Fig. 249. Looking southwards in the region near Asembagoes, eastern corner of Java. Tree savanna in a dry climate. In the distance at the left the Banjoepoetih pass; to the right in the clouds Mts. Soeket and Raoen.

Photo by the Forest Experiment Station

Fig. 250. Forest reserve around the Baloeran, eastern corner of Java. Hopeless contest against fire in a tree savanna, an extensive wilderness of grass.

25, 249, 250). The soil is full of stones and sand. The subsoil grades into a light brown, while the surface soil, to a depth of from 1/3 to 1/2 m. is black and powdery. It is possible that from the oft-repeated burning of the cogon grass, in the course of a long time, much carbon remains in the soil. It is also possible, however, that the regular recurring drying out has given opportunity for a more alkaline reaction, and carbonation in consequence of that. The first explanation is much more likely to be the correct one, because the very sandy and stony soil is pervious and thus gives little opportunity for becoming alkaline. Even so we must be cautious in coming to a conclusion. In any case it is clear that in the west monsoon more rain falls on the upper portions of the slopes than lower down. Also more falls than the pervious soil can retain against percolation. The ground rapidly soaks up this water which quickly percolates down through the ground. Part of this water comes to the surface lower down on the mountain as springs on the slopes of the ravines or elsewhere. Those seepage places are thus the ones which it should be possible to reforest. For the time being the bare ridges can well be left alone. But the water which seeps out from higher regions is also an extract of very juvenile rock material; an extract which during an intensive drought, and because of the relatively high lime and sodium content should be able to give even an alkaline reaction to the surface soil.[228] Enough has been said to show the reader that the data are inadequate to permit making any more definite statements.

After the sinking in or collapsing of the (hypothetical) original summit of the large Idjen volcano and the formation of the Idjen plateau, new volcanoes, especially in the west, south and east, originated in or close by the rim of the caldera. Of these new peaks we may mention the G. Soeket, the G. Pendil (G. Djampit), the G. Ranti, the G. Pawenen, the G. Ringgih and the G. Koekoesan. In the east the Merapi and the Kawah Idjen are younger. The Raoen is still younger and has been active, at least until the most recent times. These last-named volcanoes have with their products covered over much of the flanks of the above-named series of volcanoes. Of this series practically only the Ranti may be excepted, so that we today can speak of Ranti soils, of Merapi soils, and of Raoen soils. The products of the other volcanoes are of much less importance and hardly worth consideration.[229]

Ranti soils are found especially in the south southeastern sector, from the summit of the Ranti. More to the west are found materials from the Raoen, while more to the east are deposits originating from the Merapi and the Kawah Idjen. Although originally of more recent date than the Kendeng soils, the Ranti soils have progressed at least just as far in the weathering as the former. This is the result of the very rainy climate of the sector referred to (see the map, Fig. 6), which without doubt causes the weathering to proceed much more rapidly. Besides a considerable proportion of unweathered mineral grains, the soil also possesses a considerable percentage (15-35%) of colloidal weathering minerals, which has decreased the permeability and increased the water capacity. Because of the frequent rains no Java coffee is to be found here--rubber is the principal crop. Higher up the brown lixivium has been partially altered into pseudo-sand by mountain granulation, but this does not develop on the lower slopes and therefore at times the soil is hardly pervious enough. As a result of excessive water in the soil it does not drain properly so that there is a lack of air.

The Merapi, younger than the Ranti, has apparently erupted much fine sandy ash.[230] On the higher eastern to southern slopes the pale brown lixivium in weathering stages 1 to 2, should perhaps not be called lixivium, but because of the large proportion of fine grains, especially between 100 and 5 mu, it holds quite a good deal of water so that, provided adequate rain falls, it can carry very good vegetation. Where inadequately protected, this soil is very apt to erode off. The water easily carries

228. Cf. pp. 73-75 of this book.

229. More details regarding this in: Van der Veen, l. c., pp. 14-25.

230. Verbeek and Fennema, l. c., p. 80. Here the authors speak of a "fine, yellow to brown, mealy soil."

Photo by E. C. J. Mohr

Fig. 251. The bank of a road cut across the Watoe Dodol, the eastern foot of the Merapi-Idjen, in the eastern corner of Java. On the basalt lava lie ash and gravel layers cemented by concretionary calcium carbonate.

the material off with it and elsewhere again deposits the material as sorted layers. Consequently in many spots may be found alternating layers of coarse and finer ash and the soil as a whole is difficult to cultivate, as was also stated to be the case with the Kloet deposits.[231]

Lower, just above the sea, on the Batoe Dodol (see page 669) lie Merapi efflatas under a climate with an intense dry season. These deposits have been cemented by concretionary lime leached from high layers which, for the greater part, have already been eroded away. The cut for the highway over the basalt flow exposes to view these lime-padas forms (see Fig. 251).

According to Van der Veen,[232] the Raoen deposits show similar phenomena. The distinction is that in these soils secondary water levels can form wet and dry layers, with in one part too much water, and in another part too little. Deep working over and mixing of the ground is, however, somewhat expensive for many crops. This is especially so if at the same time measures must be taken against further erosion. As yet there are only a few plantations on these sloping and dissected Merapi soils. In the course of a long time, during some centuries, the soil conditions here will continue to become better and better, especially as to water relationships.

The last volcano to be active[233] and most important for the soil formation is Raoen. Its efflatas have found their

231. See: E. C. J. Mohr, Wetenschap en praktijk inz. lb. aangelegenh., Publ. Ned.-Ind. Lb. Synd. 7 (1915), p. 53; especially pp. 60-62.

232. Van der Veen, l. c., pp. 14-22.

233. The sequence of the above enumeration of volcanoes is that of the ending of their activity. But this does not imply that they had also commenced their activity in this sequence. On the contrary the basal portion of the Merapi is presumably much older than later volcanoes, which had already become extinct much sooner. However, from the nature of the case the soil scientist is especially interested in the last eruption and its ejecta which cover over the landscape.

way particularly toward the west and the south. Pure aeolian deposits are especially on terrains which were already more or less higher than the surrounding land, as on the northwestern part of the southern mountains, for after the eruptions no Raoen lahars could flow over them. But more northerly, thus west and northwest from the summit of the Raoen, likewise to the south and southeastwards, lahars could and did sweep down over the slopes.

Being in stages 0-1, the slopes of the Raoen are still very juvenile. The weathering has scarcely yet reached the brown stage. In the lower stretches, however, the weathering has certainly proceeded somewhat further, but then the grain size on the lower slopes also averages smaller.

Van der Veen has focussed attention upon two peculiarities of the Raoen soils, namely, (1) The so-called colloid figure. And (2) The tendency to cementing, and the formation of padas[234] (a tuff horizon).

Regarding (1)--we must not overlook the fact that Vageler's colloid figure[235] is really a figure indicating rate of permeability for water, and only indirectly by inference, gives an idea as to the colloid content. That even with a low content of weathering minerals according to the mechanical analysis, we may still have a relatively low permeability, is not so strange, if we realize that fine ash particles of from 20 to 5 mu can very well fill up the little spaces between coarser grains of 100 to 50 mu, so that there is left but little capillary space. That frequently a dustlike ash layer 5-15 cm. thick, lying between layers of much coarser sand has a cutting off action, even if always saturated with water, permitting neither downwards or upwards water movement, is likewise easy to conceive of. Hence the sound advice given by Van der Veen to eliminate, by thorough mixing of the soil, any such heterogeneity which may be the result of successive eruptions of different kinds of ash.

Regarding (2) not much else can be said than that the tendency to the formation of tuff mentioned is peculiar to the the very first weathering, as was pointed out on pages 143-144 and has been found to have occurred on the slopes of the Tjerimai (see page 617), the Merapi (see page 641), the Kloet, the Tengger complex, and the Smeroe complex. In the course of time this cemented horizon shifts from the surface downwards, and the more intensive the rainfall, the more rapidly this removal takes place. Humus (green manuring) counteracts the cementing effect not only mechanically, but also chemically, especially through the lowering of the pH. And if, for example, in the marginal region of the Raoen lahars and the Ijang slopes, by means of irrigation reddish brown or brown silt can be brought onto the too juvenile ash lands so that this silt can be incorporated into the soil, then the iron hydroxide will also retard the cementing into tuff. Here and there in the Southern Mountains one stumbles upon favorable combinations of a similar nature.

* * * * *

So much for the soils on the three great complexes of volcanoes. Of the smaller volcanoes the Lamongan is the foremost. It had been quiet a half century then again commenced erupting ash, and lava flowed out. Its rock is basic, basaltic. Because of much magnetic iron and black glass, the ash is dark colored to almost black, in fact so dark in color that laymen have though the black scoriae to be coal (see Fig. 252, page 678). As a consequence of the high iron content, as is the case with the Raoen ash, the ash and the scoriae easily weather subaerially to a reddish brown lixivium. The content of Ca and Mg is high, as in the Raoen ash. The content of the alkalies is low, especially of the K (Table 115, page 560). As to the P content there are no figures available. Yet these relatively low K figures should not be disquieting, because there is a rather dry season in the year and the soil is universally juvenile, thus great reserves are available. If there ever

234. R. van der Veen, Grondkaart, grondwater e/d Besoeki-tab. cultuur, Meded. Besoek. Proefst. No. 54 (1935).

235. See: P. Vageler, Arch. Theecultuur I (Jan., 1928), pp. 92-95, and 102-103.

Photo by E. C. J. Mohr

Fig. 252. Bocca region, north from the Lamongan, eastern corner of Java. Accumulated efflatas are dark colored ash and black cinders which have been mistaken for coal. Weathers to a very fertile dark red lixivium.

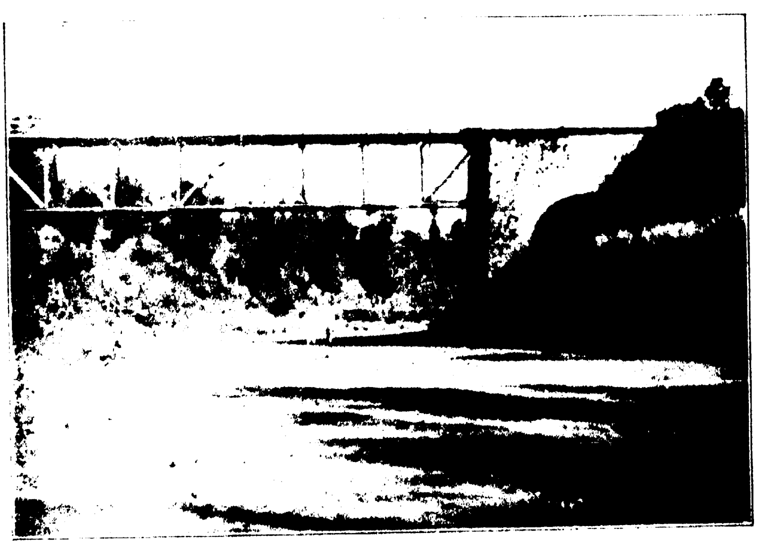

Photo by E. C. J. Mohr

Fig. 253. Bridge over the Tjoerah Boeboer, in the eastern corner of Java. In the dry east monsoon the bed of gray to black sand is dry. During floods in the west monsoon the water sometimes almost reaches the level of the road.

should be a deficiency in the soils on the slopes of the Lamongan, it would first be N, then organic matter, and especially water. Where water is adequate, that is to say where there is regular and abundant rain, on such chemically rich soil there is of course a permanent forest vegetation and in so far as it has not been destroyed, it is still there today. The Lamongan is, however, not extraordinarily high, only between 1,600 and 1,700 m. and with a quite sharp cone. Thus there is not much opportunity for rain caused by ascending air currents. Hence the summit is covered with forest. That is true for the Taroeb summit and three-quarters of the mantle, but the Lamongan summit, in the strict sense, and the lower sector, facing toward the southwest are bare. However, where water is inadequate and that is especially toward the north and more on the foot, the lower slopes, there is only a miserable vegetation. Only on the southern side, where the rainfall is more favorable are there to be found plantations or mountain cultures, such as coffee and rubber. Yet in the west monsoon also on the northern side there falls a considerable quantity of rain, but the juvenile, scoriae-rich soil is able to hold only a little water and that is just the critical factor in the following dry east monsoon, both for spontaneous vegetation as well as for crop plants. In the dry season it is a notable experience to travel in or over a broad river bed of completely dry volcanic sand, with high bridges crossing it, which through their height make us realize to what astonishing heights the rivers in the rainy season do rise (see Fig. 253, page 678).

Another smaller volcano which, however, since it has lain quiet and extinct for a long time, attracts little attention, is the Baloeran. This lies in the extreme northeast corner of Java. Basalt is the only known rock erupted by this volcano. On this mountain, of which a single peak rises above 1,200 m. there prevails an exceptionally dry climate, and, seeing that the volcano is practically completely deforested, the Government has made it and the greatest part of its foot slopes into a forest reserve. This is in order to try and prevent the repeated burning of the miserable forest of the higher stretches which in itself has already a difficult existence. This forest is continually the victim of the fires which spread up from the grass lands of the lower coastal stretches against the slopes and there cannot be extinguished (see Figs. 250, p. 674; 25 , p. 680). It is evident that if once the forest fires are checked, gradually more forest will again occupy the land and more soil will be held fast on the slopes, a result which will in its turn be to the advantage of the forest. Then it is also worthy of note that the water flowing off from the upper slopes will flow more constantly and the small irrigated region at Badjoelmati, for example, can be extended.

Whether, however, even complete exclusion of fire from the lower eastern and northern slopes of the Baloeran will ever result in its being covered with closed forest, still seems to be an open question. According to Van Steenis,[236] one need not doubt at all that this entire mountain would be covered with closed forest, and man, because he is the cause of repeated burning, is the only reason that the mountain is not forested today. Cape Baloeran is generally known as the very driest portion of all Java. Rainfall observations however, are entirely lacking. But, if we take[237] those of Ardjasa, Asembagoes and Soemberwaroe as a guide, then the average rainfall of the region referred to certainly will not rise above 950 mm. per year, of which the 8 months with the least rain will average but 200 mm. and in the 6 driest months perhaps not even 100 mm. The average number of rainy days will not exceed 65 for the year, 16 rainy days for the 8 driest months, and 7 rainy days for the 6 driest months. Then if we also take into consideration that in several years in succession continuous rainless periods of 7 to 8 months occur in this tract then that "closed forest" supposed by Van Steenis to have existed here must indeed have been a

236. C. G. G. J. van Steenis, ...origin of deserts in general. Bull. Jard. Botan. Buitenzorg Ser. III, Vol. XIV, I (1936), pp. 50-55.

237. From the Verhand, 24 van het Kon. Magn. en Meteor. Obs. te Batavia, supplemented by the figures for 1929 and 1930.

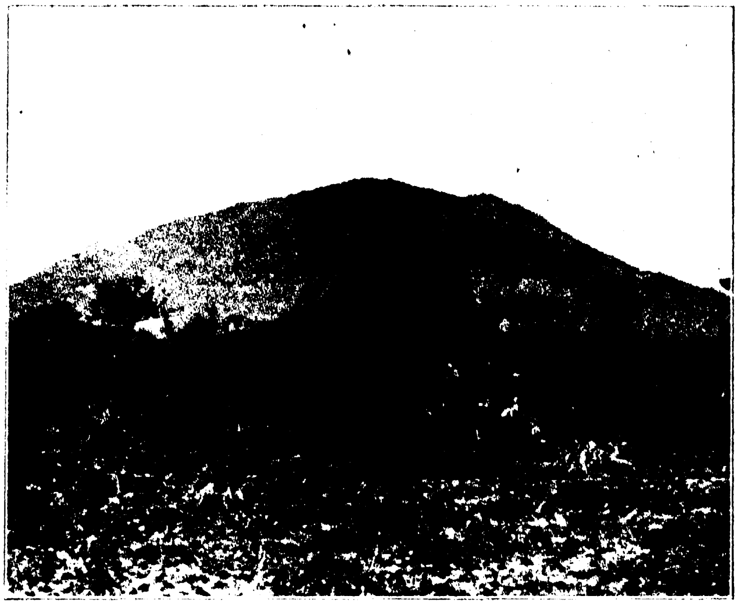

Photo by the Forest Experiment Station

Fig. 254. Mt. Baloeran in the eastern corner of Java. In the foreground the burned bare flat where the Madoereese, guided by the new shoots dig for ubi (Dioscorea) tubers. Only a very few sorts of trees will withstand the annual grass fires. The slopes of the Baloeran above are still covered with forest, but it is irregular and with openings.

very special sort.[238] While Asembagoes has a high back country which can supply irrigation water, it is a very big question whether the small Baloeran summit can in this respect function adequately. In short, whether in tropical and subtropical regions, without a supply of water, with a rainfall of less than 1 m. and with frequently occurring continuously rainless periods of more than 200 days, the savanna and desert vegetation should only and exclusively be ascribed to the forest-destroying influence of man, is still only an assumption, which remains to be proven.

However this may be--the forest referred to on the slopes and on the low foot would, presumably, for the greater part, drop its leaves in the dry season so that the soil during this time would also be even seriously exposed to the direct rays of the sun. For although originally a layer of fallen leaves would lie on it, the strong hot east monsoon would not leave these leaves unmolested, and would even blow some of the soil from the bare ground (wind erosion). The condition which now prevails[239]--is the following: already for many decades, annually in the time of the scarcity of food at the end of the dry monsoon many hundreds of Madoereese come over from Madoera and burn off all the cogon and forest, so that among the young sprouts starting up after the burning they easily locate the tubers of ubigadung (Dioscorea hispida Denst.--D. hirsuta Bl.) and dig them out (see Figs. 250, 254). It is

238. In this connection compare the figures from: Ch. Coster, Verdamping v. versch. vegetatievormen, Tectona XXX (1937), pp. 1-124.

239. According to monthly reports of the Opperhoutv. P. K. Heringa, cf. at the same time; T. Ottolander, Alg. Lb. Weekbl. N.-Indië, 2 (1918), 793 and F. H. Hillebrand, Oewi- en gadoengsoorten in djatibosschen, Het Bosch, I (1933), pp. 47-55.

obvious that with this treatment there is not much chance that normal brownish red lixivium can form through intermittent leaching out in the west monsoon. The burning year after year certainly results in so much charcoal falling onto and into the soil that this becomes a dusty black, in so far as the charcoal is not blown out by the wind and disappears.

* * * * *

Enclosed by the circular road from Bondowoso, through Sitoebondo, Panaroekan, Besoeki and back to Bondowoso there is a mountainous region to which Mt. Goenoeng Ringgit, as well as G. Djember and G. Beser belong. G. Ringgit is an old volcanic ruin, notable in that the rock, at least the greater part, contains leucite, solidified out of a relatively K-rich magma. That the soils, originating from this material through intermittent weathering should be especially rich in K does not appear to be borne out in practice. But to this point we will return again. Apart from that in the analyses,[240] included in Table 115, page 560, there are still a couple of special points which are worth noting. 1st--the high P content which also characterizes the leucite rocks of the Moeriah, and 2nd--the low Na content, definitely lower than that of the Moeriah rocks. The K_2O content varies around 6%. One of the analyses (No. 2) clearly shows that the Ringgit had also ejected Na-rich and K-poorer basalts.

As to the climate, this holds approximately to the average between that of the Baloeran to the east, and the northern slopes of the Tengger to the west. In each case a marked dry east monsoon and a moderately rainy west monsoon prevail. As a consequence, on the slopes of the Ringgit intermittent leaching is the prevailing weathering form, which leads to a brownish red to red lixivium, moderately leached out, but slightly humous. On this mountain also, in the east monsoon heavy cogon and forest fires regularly occur. A few years ago in one fire "on the slopes of the Ranoe mountain" which is the western part of this mountainous region, "more than 2,000 ha. of poor upland rice fields of the natives were cooked along with the native forests which continued to burn." Three years later it was "already to be observed, that in so far as there were present remains of the vegetation on these lands, these covered the surface quite well."[241] With effectual measures for the control of fires, we may here expect the development of a decent monsoon forest. As a consequence of that an equalizing of the discharge of the small mountain streams which supply water for the irrigation of the coastal plain also can be expected.

* * * * *

The last mountainous region to be discussed here is the Southern Mountains, lying to the south of the Raoen and Idjen complexes. This is the oldest, for its formation extends certainly to far back into the Tertiary. The rocks consist principally of conglomerates and breccias of hornblende and pyroxene andesites[242] also silicified tuffs, but there are also sandstones, quartz porphyry, diabase and limestone.[243]

In general, on the slopes and on the summits the soils are red. These are different sorts of red lixivium depending upon the proportions of iron oxides and hydroxides and quartz sand. If in old red soils the iron oxides are entirely dehydrated then the soil is heavy and plastic. If the iron oxides are still for the most part brown to yellow, then the soil is not plastic and heavy, but looser and light.[244] Also the quartz sand makes the soils lighter.

240. See: Jaarb. Mijnw. N. I. (1932-1933), p. 88 (1935); and De mijningenieur 14 (1933), pp. 197-199. Cited in: K. Keil, Ueber d. Vork. v. leucitreichem Basalt a. G. Ringgit (Java), Centr. bl. Min. Geol. Pal., A (1933), p. 245.

241. See the Mem. v. Overg. van Res. A. H. Neijs (Juli 1929).

242. The analyses recorded by Stoehr (1873) are indeed quite incomplete. See Table 115, p. 560.

243. Cf.: Van der Veen, l. c., p. 2.

244. Cf.: pp. 144, 148, and Fig. 43, p. 176.

According to Van der Veen[245] the degree of heaviness varies from 4 to 10. Only the lighter sorts are really suited for cultivation.

In the valleys of the rivers are more subaqueously weathered, gray soils. They are heavy, if they are free from sand. But they are lighter, if they contain quartz sand or Raoen sand which has been carried onto them. Also here again only the lighter types are suited to cultivation. They were originally planted to coffee, and later to rubber. Following these, native crops are also grown.

It is worth recording that where these gray soils have been in gardens for many years under good drainage "most times they have become brown to some degree"--(Van der Veen).

Except when much juvenile Raoen material is mixed in through them, neither the soils on the slopes nor those in the valleys are chemically rich.

* * * * *

Now as we consider the plains of East Java, we should remember that all the materials of which they have been built up have come from the above already-considered mountains and complexes of mountains.

The Idjen Plateau occupies a special position. It is in no sense a plain built up by river action, but a high crater plain, surrounded by and spotted with a number of large and small volcanoes, the products from which have flowed over and are scattered about, so that it is frequently difficult to point out, from just where the material has come which makes up the ground on which one happens to be standing (see Fig. 245). Since in this book we are not attempting to do a monograph of Java, still less of Besoeki and least of all one about the Idjen plateau, we cannot very well go into details. We must be content with the statement that the combination of loose and friable volcanic soil, in elevation varying from about 900 to 1,600 m. with a climate for this elevation notably dry, make very favorable growing conditions for Coffea arabica, which is raised here on various plantations. The surface soil is often dark gray to black, and the subsoil light yellowish brown in color. The whole is friable, never plastic or heavy. The content of good humus is not strikingly high. It is quite easily possible that the surface soil is considerably darker in color than it otherwise would be due to the mixed-in charcoal, which has come from the annual burning of cogon and coarser grasses which has presumably been occurring for a considerable time. Now and again over the whole region there have been lighter or heavier falls of ashes. Because of these reasons it does not seem to me likely that the Idjen plateau was ever covered by a solid tropical high forest. The very long time necessary for soil formation, and perhaps also the requisite water in the soil have presumably been insufficient. The description by Junghuhn,[246] almost a century ago (1844), points in the same direction. Where there is only mention of "grass plains and young tjemara (Podocarpus) shoots at most 25 years old" (see Figs. 245-247, pages 669-672).

A plain, lying much lower than the Idjen plateau, but yet a relatively high plain, is that of Malang, which is an elevation of between 300 and 500 m. above sea level. It is a triangular region: in the south the Southern Mountains, in the west stand Mts. Kawi and Ardjoeno, in the east stand Mts. Tengger and Smeroe. The three corners, each in its turn, could have been a threshold for the outflow of water. For example, it is indeed quite possible that long after the Kawi lahars had reached the Southern Mountains but the Smeroe was still building itself up, the Tengger and Ardjoeno held out their hands to each other in the saddle of Lawang. Then the surplus water of the plain must have flowed out toward the southeast. Perhaps at one time the water ran northwards; while now the plain is drained through the southwest corner, through the Brantas valley. But in any case we can safely say that after the elevation of each threshold, which had occurred in the geologic past, a smaller or larger portion of the plain was submerged,

245. Van der Veen, l. c., pp. 26-27.
246. F. Junghuhn, 2e Nederl. Uitg. van "Java," III, p. 1017 ff.

again later to be drained dry through both cutting down of the threshold, and through filling up of the plain behind the threshold.

Already we have considered many smaller and larger plains on Java, of which it has been, or might be, said that they have once been lakes. The limitation to a particular period of time is unnecessary. In a volcanic land with countless eruptions and a still greater number of lahars, damming up or draining out of rivers can have occurred again and again and for each earlier lake plain laid dry least of all is it necessary to suppose that it was laid dry all at once. Nor is it any more necessary to believe that the surface soil of such an earlier lake plain must now also show signs of the earlier subaqueous weathering. That this is obviously so, will be understood when it is realized that after draining of the lake new surface coverings have occurred subaerially, as ash out of the air, as lahars or as the usual deposits of river sediments over the surface, so that the earlier lake soil can be found only by boring or when it is exposed in river banks.

Consequently the Malang plain is of very heterogeneous material and only a part of the "plain" is really flat. There are not only mighty ridge-forming lahars, which have flowed down in especially from the eastern side, but even lava streams, which form ridges and bubbles. On the other hand erosion has rounded off the edges of the gorges which the rivers have cut down deep into the plain and have in that way attacked the plain.

A large part of the plain is covered by a peculiar gray, sometimes more or less sandy, but sometimes very fine grained and heavy surface soil on a brownish red subsoil. The latter is clearly an earlier surface soil, subaerially weathered to the usual brownish red lixivium. The plain must have lain exposed to the air for a very long time to permit the formation of such a soil. The gray layer differs in thickness, from $1\frac{1}{2}$ or 2 m. at the most, to a few decimeters where it is the thinnest. Where the layer was still thinner it has disappeared or at least at present is not easily recognized due to the cultivation of the soil, etc. Why has this surface soil, apparently built up from the younger products of the Smeroe, not become brown rather than gray? The color, pointing to the subaqueous weathering, suggests the possibility that the outlet of the plain was dammed up, submerging the land with the formation of a lake, and as a consequence subaqueous weathering took place. For the formation of a lake the terrain, however, must have been flat, not having actual differences of elevation of a couple of hundred meters. It is possible, however, to imagine that a young ash layer, deposited on an old, more or less senile red soil, but much less pervious than the ash, would result in the formation of iron concretions. This would be especially true if a secondary water table occurs at the boundary between the red soil and the ash. Furthermore if a vegetation developed which had the effect of retarding the flow of water off over the surface, so that a large part penetrated down into and entirely saturated the ash layer, then the iron concretions would be more likely to form. Even though the surface layer as such did not become swampy, but still being saturated with water through the difference in perviousness, the soil must have weathered more or less subaqueously--in other words, it became gray, and in this case has remained gray. Now the forest is gone and almost all of the land is in paddy for which there is sufficient water. But, where the soil has been worked over, and is aerated as a result of drainage, it tends toward a light brown color. The reader will at once understand the changes which bring this about.

* * * * *

Besides a couple of insignificant Tertiary hills we have now left for discussion only the coastal plains which have been built up by streams out of the material from the volcanoes and the volcanic complexes which we have already discussed. These plains differ, however, according to the nature of material, according to the time during which this was deposited, according to the topographic position where the material came to rest, and upon its position with reference to the ground water and the climate under which it came to rest,

thus the weathering form and the weathering stage.

As a rule, since the greatest part of the plains referred to have an adequate slope, they drain well even in the rainy season, but even so concave bits do occur here and there. Therefore they are marshy and show the effects of subaqueous weathering. These spots possess the least sand and the soil consists of heavy gray and grayish loam and clay, sometimes even black in the wet condition.

At the elevation of Bangil the plain is built up out of products of the Ardjoeno and the Tengger. The higher lands which drain well are all brown, running to brownish red. Since unweathered fine ash is mixed in with them, even these fine sandy reddish gray loams are light soils. In the east of Java this type of soil is called "tarapan." Unusually excellent examples are to be found in the surroundings of Asembagoes. The dark gray, lower lying clay, however, is heavy, but still not so heavy as the black clay which cracks so strongly upon drying. This type occupies some weakly convex areas which have a gentle slope from the hinterland toward the coast.

It is the same "black earth" which is also found on flat humps in the Brantas delta and also along the north coast of Western Central Java and in Solo and Madioen. The climate at Bangil also includes the same strong east monsoon.

But now the question is: does one have here the same parent material? If so, then where has it come from? So we come to the hypothesis that the Ardjoeno and/or the Tengger in the very first beginning of volcanic activity may perhaps have ejected andesitic rock with little dark minerals as hornblende and pyroxenes, and at the same time much colorless glass. The existence of these rocks, however, has not yet been demonstrated. Moreover, farther eastwards there is found the same black earth, both in the plain of Probolinggo and still somewhat farther east, to the north from the Ijang. But there are no further occurrences, until in the plain to the south of the drainage basin of the Kali Setail, close to Gradjegan. There is none in the great plain which extends from Loemadjang to Djember and Poeger.

As long as neither geological nor soil map of any of this East Java region is available, we can only speculate as to how and why this black earth was formed. We cannot yet give an adequate and conclusive explanation for its formation.[247]

In each case the black earth is senile. Therefore its formation must have begun a long time ago. Thus there is no need to search for it on the juvenile ash in the neighborhood of volcanoes which are still active today. And if the efflatas are pronouncedly basic and rich in iron, such as those of the Lamongan and the Raoen, it would be particularly useless to look there. Thus there is no black earth in the Loemadjang, the Djember, or the Banjoewangi regions. Also the drainage basin of the Sampean has been covered over with Raoen efflatas, so that the black earth is also lacking between Bondowoso and Sitoebondo and in the triangle north from Sitoebondo. It is true that in the southeastern part of Sitoebondo there is a very low, marshy tract with darker to almost black swamp soil, but this is an entirely different soil, still juvenile, sandy, and not nearly so heavy. Moreover this soil lies on a concave surface, while the true black earth always occupies convex surfaces. Gray to black, juvenile, even sandy swamp soil in concave positions is for example also found in the plain between Loemadjang and Poeger, where formerly the Besini Swamp was. At present these swamps for the greater part have been drained and converted into fertile cultivated fields. And so the gray color begins to change into a brown.

The most senile, or better said the earliest and longest weathered, but still not quite weathered-out plains lands are found close to the volcanoes which have been inactive the longest, thus north and south from the Ijang,--localities into which only a minimum of fresh ash has been able to arrive from the younger volcanoes. Indeed quite brownish red to deep red soil types are to be found, with gray, heavy clay lands in the concave depressions between them, especially on the southern side, where the rainfall is heavier. On the very dry northern side, south from Probolinggo, now and then soil profiles occur that are

247. See the general discussion relating to this black earth; pp. 164-170.

different from any others on Java. An example of this is as follows: Down through a dark grayish red layer of loose material a small stream has cut a narrow ravine to approximately 10 m. exposing a lava stream of basalt, showing a network of lime concretions lying on the basalt, while in the deeper part of the soil above it there is but very little calcium carbonate and the surface soil has none at all. One can picture to himself how the west monsoon rains have robbed the higher lying loose material entirely of lime and converted the surface soil to red lixivium. But in the long, intense dry season none of the calcareous water could climb back up toward the surface. However, water cannot help evaporating out of the iron-rich loose soil, so that the lime must precipitate. The lime concretion horizon, which elsewhere, in younger efflatas sometimes is even found at only 1/2 m. here wanders gradually down to 10 m. depth and is stopped there by the impermeable basalt flow. During the course of a long time to come, in each west monsoon the rain water percolating down through will also again dissolve the deep lime concretions and via the streams the lime will be carried on out to the sea. $CaCO_3$ concretions are thus an intermediate phenomenon which, for example in the continuously moist regions of Java, can never be found. Even here ultimately the soil will become a lime-poor, concretion-free, red lixivium.

Everywhere else the soil is more juvenile. The plain around Loemadjang is a product of the young and very recent mud flows from the Smeroe. The plain of Djember is composed of similar materials from the Raoen. The southern part of the plain of Banjoewangi is derived partially from those materials from the Raoen, but the more northerly part of the material is from the Merapi. The plain of Asembagoes is built up for the greater part by the Banjoe Putih from efflatas it has carried out from Merapi, but that portion to the north of Pradjekan, however, is of Raoen products, which one finds further along the Sampean as far as the delta, north from Sitoebondo. At the present time almost all these plains are well irrigated. But if the three great volcanic complexes of East Java were not so large and so high this would not be possible. As a consequence of this good water supply, the conditions for growth of rice and other crops (sugar cane) here in this sunny, dry climate are especially good. Definite evidence of the example appears clearly in the figures of yield of the paddies.

The average production[248] of East Java (that is to say, the districts of Malang and Bondowoso) will not lie far from 30.5 quintals per hectare, thus notably above the average for Java as a whole, which is about 22 qu./ha. A few districts have an average even higher than 35 qu./ha. These are:

Sitoebondo	36.7 qu./ha.
Rambipoedji	36.5 "
Poeger	37.3 "
Gentoeng	36.8 "

Of these Sitoebondo has an extraordinarily dry climate. While the entire peninsula has 7 dry months with less than 60 mm. rainfall as against 4 wet months with more than 100 mm., the annual rainfall, which falls in about 67 rainy days totals 1,150 mm. In the 7 dry months during an average of 11 rainy days, about 170 mm. falls while in the very driest months in an average of two rainy days about 34 mm. In certain years (for example 1929) not a drop fell in 7 months. The land lies low and the very juvenile soil, here and there decidedly sandy, is adequately permeable. Thus because of the strong evaporation under continuous sunshine, conceivably favorable conditions prevail for the enrichment of the soil from the soil moisture and the irrigation water. This is reflected in the high yield of paddy. Also the cultivation of sugar cane gives high quantities of cane and sugar.

On the south of the Rambipoedji district is the Poeger. It lies on the foot of the Ijang but even so the district has now and then received from the east (Raoen) and from the west (Smeroe) ash rains which have rejuvenated the soil. Some soils have been covered over with silt from a flood, while the older, farther weathered Ijang soil gives an adequate water capacity. Closer to the sea, in the Poeger district the slope of the land is less, the ash is

248. These figures have also been taken from the repeatedly referred-to "Landbouwatlas" (1926).

finer and holds more water, which compensates for a lower content of Ijang weathering lixivium. The climate with a distinct but moderate dry season, which becomes somewhat longer and drier the closer one approaches the coast at Poeger, is at the same time favorable for good yields of paddy. It may be expected that in the near future the yields will not be less, for now the soil in general has a neutral to slightly alkaline reaction, while the optimum reaction for rice seems to be a slight degree of alkalinity[249] namely, from 6.8 to 7.9, thus just about the same as for sugar cane.[250] Tobacco, on the contrary, prefers a weak acid reaction, a pH of 5 to 6[251] and tea a soil even 10 times more acid, namely with a pH from 4 to 5.5.[252] Rubber is similar to tea in this respect.[253] Cinchona, on the contrary, prefers a pH of 5.5 to 6.5,[254] while oil palms give the highest yields at about a neutral reaction.[255]

Since paddy (rice) is planted uninterruptedly on brown and red lixivium (West Preanger) it is quite generally believed that rice prefers such soil types and these are all more or less acid,[256] thus it has been believed that its optimum was on the acid side. The British Indian investigators, however, obtained another result which seemed to indicate the need for studying the question more closely for Javan soils and conditions particularly with reference to the questions of fertilization.

Meanwhile for the sugar cane districts we can obtain approximate average pH values from the figures of Arrhenius,[257] and if we then compare the average paddy yields for approximately the same localities, as given in the text of the Landbouw atlas, the following table (Table 139) results:

Table 139

REACTION AND YIELD OF EASTERN JAVA RICE SOILS

Group of Sugar Mills	Approximate average pH	Approximate Average yield of paddy in quintals per hectare
Besoeki	7.6	about 32.2
Probolinggo	7.6	" 29.5
Sidoardjo	7.6	" 30.5
Pasoeroean	7.5	" 28.7
Djombang	7.4	" 30.5
Modjokerto	7.4	" 27.8
Kediri	7.4	" 27.8
Tegal	7.4	" 26.9
Madioen	7.2	" 20.0
Cheribon	7.0	" 20.9
Jogjakarta	6.9	" 22.6
Soerakarta	6.9	" 20.0
Pekalongan	6.9	" 18.3
Semarang	6.8	" 21.7
Banjoemas	6.6	" 24.4
Northern Coast of West Java (no sugar cane cultivation)	5.9	" 23.5

From these figures (Table 139) there appears to be a close correlation, indicating a trend in the same direction as do the results of the study by Singh and Mitra. If further research on Java does really establish the above provisional conclusion, it is obvious that it cannot have other than a significant influence on the

249. B. N. Singh and G. P. Mitra, Plant growth in relation to H-ion changes in its medium, Ind. Jl. Agric. Sc. VII, 2 (1937), pp. 327-348; especially pp. 335-336 and 331.
250. O. Arrhenius, Onderz. Zuurgr. suik. gronden Java, Meded. Pr. st. J. S. Ind. No. 6 (1927), p. 210. See also: p. 566 of this book.
251. P. A. Rowaan, Onderz. Zuurgr. grond Deli tab. cult., Versl. 12e Vergad. Vereen. Pr. st. person. (1931), pp. 128-133 (1932), especially p. 130.
252. P. M. Prillwitz, Invl. verzad. toest. grond op groei jonge thee; the same: verslag, pp. 134-139, especially p. 138.
253. A. Kortleve, Invol. bod. reactie op ontw. hevea en oliepalmen; the same: Verslag, pp. 140-150.
254. P. Pzn C. Spruit, Eenige bijz. h. hooggel. grond. i. v. m. basentoest., the same: Verslag, pp. 34-62.
255. See under note 253: pp. 151-156.
256. J. Th. White and H. J. Hardon and H. J. te Riele, System. zuurgr. bep. b. gronden v. Java, Versl. 13e Verg. Vereen. Pr. st. person. (Buitenzorg, 1933), pp. 21-44, especially pp. 29 and 31.
257. Arrhenius, l. c., pp. 210-215.

questions of irrigation and fertilization of paddy. For example, on rice soils with a pH less than 6 most probably one would not use acid N and P fertilizers. Conversely by preference one would use fertilizers with an acid residue on lands with a pH greater than 8, etc.

In short--from every point of view it is understandable why the plain between Rambipoedji and Poeger gives such high average yields of rice.

Genteng, in the plain of Banjoewangi, also has very high yields, although in many places the large amounts of gravel must be quite a hindrance to the growth of the roots. But this is lahar gravel from the Raoen, supplemented with finer deposits from the Kali Setail and other rivers; thus it is very juvenile material. Besides that, the climate is very reliable, no heavy driving rains, but more gentle rains continuing throughout almost the entire year. With about 1,700 mm. of annual rainfall there is but one average dry month, 4 months with between 60 and 100 mm. and 7 months with more than 100 mm. thus the climate is "wet" (Kradenan). As a result the soil has become a sandy and gravelly tarapan.

Into this region apparently the immigration of new inhabitants can still continue for a long time to come in the same way as it has gone on for the last quarter century; the soil is productive enough for that. In 1930 the density of the population was still scarcely 111 persons per km.^{2} It is true that at that time in the south there were still extensive uninhabited tracts, but even if the entire population were collected onto the northerly 40% of good, irrigable tarapan soils, then the density of the population would still be but about 277 which is about equal to that of the Rogodjambi, in which are included many uninhabited mountainous portions. It is also worthy of note that more inhabitants do not live along the lower course of the Kali Baroe. Since this river also comes from the Raoen, where it flows over the land, or the water is used for irrigation, it must certainly bring along with it much fertility. Twenty years ago I knew well that in the entire region south of Kredenan not a soul lived, except those few men in Gradjegan, on the sea at the end of the road to the south. Cogon, wild cane, now and then some forest, larger deer, tiger tracks, and peacocks, were all that one saw westwards to the Kali Baroe and also northwards to the Gambrian and Genteng. Ten years later, as shown by the topographic maps of 1924 and 1926, spreading out from the north there was a considerable distribution of villages which had come into existence south from the Kali Setail, but no further than that.

According to Van der Veen,[258] in the region about Goenoeng Srawed, which is in the northwestern part of the plain here being considered, "the structure of the soil is just like that of the Ijang soil." Subaerially weathered the soil is a reddish brown lixivium, apparently quite old. Subaqueously weathered there is a "gray, heavy, difficultly-permeable marsh clay." The reddish brown soil is suited to coffee and rubber; and it is also adapted to all sorts of crops of the native inhabitants. The gray soil may be recognized as an "overwash of sandy Raoen soil." It should be easy to make quite productive paddies on this soil.

This line of thought was apparently also that of the engineer in charge of the Kali Baroe (later Banjoewangi) Section of the Pekalen-Sampean Irrigation Subdivision.[259] Repeatedly during a number of years the dams of the natives were repaired by the Irrigation authorities, while in the meantime test harvest cuttings of paddy[260] had shown yields as high as 43.5, 61, and even more than 70 quintals per hectare dry paddy, with averages of between 31 and 42.5 qu./ha. Naturally the interest in this section increased and the Irrigation Authorities prepared the plains for a large irrigation scheme most of which was put into execution in the years 1935-1936.[261] When one reads in the series of reports of the Irrigation subdivision, how from year to

258. R. van der Veen, l. c., pp. 27-28.

259. The Agricultural Extension Service, possibly through lack of personnel, has never given any attention to either west Genteng or South Genteng (see their Jaarverslagen 1917-1936).

260. Jaarversl. Prov. Oost-Java (1929), p. 310.

261. Jaarversl. Prov. Oost-Java (1936), pp. 139-140.

year new inhabitants settle and make paddies, there is no reason to doubt the success of the South Banjoewangi irrigation on soils rejuvenated by the Raoen deposits.

But the eastern part of the plain is one great body of "black earth," which the reader, after Soerakarta and Madioen, will recognize as a heavy, black clay, deeply cracking upon drying, with iron concretions in the form of hail ore. Here, however, there are no concretions. The terrain slopes slightly from the northwest toward the southeast and for the most part lies between 25 and 75 m. above sea level, but a small part in the west is as high as 100 m. and more. Whether toward the east it goes much lower than the 25 m. contour line, I have not myself seen, nor have I found anything concerning this in the literature. It is a region older than the low Banjoewangi triangle north of it, for otherwise the Kali Setail would not have run and bent toward the east. But how did this region originate? How did this black earth come about?

If we think of a formation above the level of the sea, developed from the iron-poor material, as in East Central Java then there is not a single indication that this soil originated from pale, iron-poor tuffs. Besides the climate in the east monsoon is certainly not dry enough to form such a soil and one should have to accept that earlier, at the time of the forming of the black earth, a climate had prevailed with a distinct annual dry season of at least 3 months. If one supposes that this soil was formed from marls, it is necessary to postulate an earlier extensive marl formation in this place, a formation which subsequently has totally disappeared. Only at Gradjagan are the easterly remains of the Southern Mountains consisting of andesitic breccias still "covered by a sandy white marl lime."[262] Other than that, the nearest thing to a marl which can be found is only limestone (on Blambangan, for example), which would be much more likely to give rise to the formation of limestone red earth. If we agree with Verbeek's[263] third point and think of an earlier shallow arm of the sea between Java and Blambangan, then this must have disappeared through an equal or an unequal elevation of the land. In the east there was but little change but in the west the elevation must have been as much as 100 m. or more. The black earth would then develop as the coastal vegetation gradually won land from the sea, thus in coastal marshes, as a subaqueous soil formation, going over into an amphibian soil, and finally becoming dry swamp clay. But then in the deep profiles also, as at Djoewana, one would certainly come upon layers with shells and perhaps coastal peat. But of such things nothing is really known. Putting it briefly, without thorough investigation in the field a conclusive answer to the above questions cannot be given.

There is one practical point which here deserves to be mentioned. The black earth here as everywhere else, is extremely poor in phosphorus. Irrigation water from the Kali Baroe and the Kali Setail brought onto this soil must indeed be very rich in that element, and decent yields of rice should be obtained on this soil, otherwise it will be necessary to apply intensive P fertilization and very probably also fertilization with N. There are certainly "natural" reasons why on the densely populated island of Java down to today this great region still lies as good as uninhabited.

Regarding the Blambangan region, Junghuhn[264] supposed that two centuries ago the entire flat land, from the present day Banjoewangi southwards to the limestone mountains on the coast....was covered with paddies. For the part as far as to about the Kali Setail I can easily believe that that could have been the case, but concerning the great flat black earth plain, I can hardly believe that it ever was in paddies. There was no irrigation water on that higher terrain, hence any paddies there would have had to depend upon the rain alone. With the great deficiency of P in that black earth it is not difficult to imagine the very low yields which could be expected from such paddies.

Moreover, Junghuhn saw the entire

262. Verbeek and Fennema, l. c., p. 60.
263. Verbeek and Fennema, l. c., p. 62.
264. F. Junghuhn, Java, 2e dr., I (1853), p. 211.

plain only after the disappearance of the inhabitants, when it had been recaptured by "the majestic forest, which had overwhelmed one acre after another," etc. Neither in this can I agree with Junghuhn's power of imagination. While it is very likely that on the colluvia and alluvia of the Raoen a luxuriant secondary tropical high forest grew up, it is hardly likely on the black earth which is several meters thick. It is much more probable that two centuries ago, and even some centuries earlier the same condition of a grass plain prevailed with occasional groups of poor, small trees, such as is the case today. At most one might suppose that at one time the small clumps of trees were somewhat larger and higher, but not even in a thousand years would tropical high forest, like that in the lowland north of the K. Setail grow up here. Only western technic with irrigation water from regions of juvenile soils can rejuvenate the soil and make the land fertile.

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MADOERA

According to its nature, the island of Madoera belongs with the northern part of Eastern Central Java. Like this part of Java it is composed of Neogene rocks, marls and limestones, while volcanic activity is entirely lacking.

Northern and southern calcareous ridges can be differentiated, between which, coming in from the east, a wedge-shaped calcareous ridge penetrates. This central ridge both at about Pamekasan, and again somewhat west from Soemenep, divides into two ridges so that, for example, a profile north and south across Pamekasan crosses 4 calcareous ridges. These ridges are not all alike in composition of the limestones. Especially does the most northerly material diverge in that it possesses a considerable content of sand, mostly quartz sand, but also grains of orthoclase, plagioclase, tourmaline, zircon, and other minerals originating from old massive rocks, presumably granite. It is of precisely the same composition as the northern limestone ridge in Soerabaja and Rembang (cf. pages 655, 656). More southerly ridges do not show this coarse quartz sand. The farther south one goes, there is first more fine grained quartz, thereafter more minerals of young volcanic nature, plagioclase, hornblende, pyroxene, and magnetite. Even pale and dark colored glass can be seen.[265] Except for a small proportion of remains of a calcareous algae (Lithothamnium) the lime of all the limestones is present in the form of remains of various kinds of Foraminifera. There has never been any mention of material from coral.

According to the map of Verbeek and Fennema the region of the marls lies between the northern and the second or third calcareous ridges. But since it is said of these rocks that "upon dissolving in HCl they give a residue, which can amount to from 40 to 60%, and consists for the greater part of andesite grains," the use here of the term "marls" is hardly correct. Materials such as those occurring here are more properly fine sandy or tuffaceous limestones. They are, however, marly in that through weathering these admixtures can give rise to a quantity of clay, and this is certainly important.

But as related to the largest part of Madoera, the soil on all these rocks is formed under a climate which has a very dry east monsoon in addition to a short, quite strong rainy season. Where, as on the northern calcareous ridge, the rock as well as the soil from that rock is quite pervious, it must certainly form red lixivium and because of the large content of quartz sand, the lixivium must be sandy, pale red or red. But where, as on the so-called marls, even already before all lime was leached out, heavy clay had formed through weathering, and thus the perviousness had been reduced. Conditions came about such that grayish black marly clay developed. But in the soil profile the subsoil is many times still a grayish yellow. In the second and third ridges, which is a transition region, besides a decrease both in quantity and grain size of the quartz, more and more fine andesitic, clay-producing minerals may be noted.

265. Cf.: Verbeek and Fennema, l. c., p. 52.

As a result because of the presence of that fine, unweatherable quartz dust the grayish black clay in the north is also more fine sandy and loamy. In the south this is less the case. Just as does the ridge of Pengantenan, here and there the most southerly calcareous ridge also carries brownish red lixivium. The rock there apparently possesses adequate andesitic, iron-rich accessory materials to produce pervious soil.

All these accessory substances, espcially the quartz sand and quartz dust, make the soil very erosive; erosion by water in the rainy season, dry erosion (dry wash, when dry winds blow) in the dry season. Thus, in spite of the small total annual rainfall the erosion is heavy; especially now that the entire island has been deforested. But from ancient times the products of erosion have formed plains between the ridges, and also along the coast in the east and west.

Where these plains are sandy and lie high enough to be subjected to subaerial weathering, the soils are pale yellow to chamois colored. Where they are free from sand, and must be called heavy loam or clay which, moreover, still lies under subaqueous conditions, the color is gray to grayish. Between these two soils groups one naturally finds all sorts of transitional forms.

Above we have already mentioned the very dry east monsoon. This is just as strong as at many points on the northern coast of East Java, but is much more fatal for the soil and the vegetation of Madoera, since here no high mountains stand in the back country to supply ground water and irrigation water which could make up for the deficiency. Just stop and think what it means if, for example, in 8 months but a few mm. of rain falls in a few little showers of at most 2 mm. each. This moisture naturally cannot penetrate into the soil to any significant depth before it is all evaporated. A permanent vegetation cannot exist on that, unless either the vegetation, such as cacti and some palms (see Fig. 255, page 691), has practically no transpiration; or loses its leaves (see Fig. 256, page 691) such as wodier (Lannea grandis) and teak. Vegetation might exist if the soil is provided with water from underground from some hills in the region, or possesses a very great water capacity and water-supplying power.

Madoera may certainly indeed be called an ideal region for observations and experiments relating to the water supplying capacity of soils, since this phenomenon is here so extremely important. This differs for each kind of plant. Here I call attention to maize (corn), which is such an important food crop for Madoera. Maize is no xerophyte, and is very different from cacti. It is also different from teak, as maize does not drop its leaves in the dry season, and if the especial circumstances of subterranian water flow or irrigation fail, then the maize must live on the water which the soil can give it, within the range of its roots. As has already been mentioned on pages 611 and 637 this supply depends upon 1st--the available quantity of water, and 2nd--the rapidity of delivery to the roots where these take it up. As to (1) it may be remarked that the determination of the quantity is still not so simple. In order to make a beginning let us note some of the practical considerations in this matter.

At a given point in the soil profile the maximum water capacity M is the quantity of water which the soil there contains at the end of the rainy season, shortly after a heavy shower of rain. If the roots take the water away, then a point is gradually reached at which the pF[266] of the soil has risen to about 4.2 (corresponding to about 16 atmospheres "suction force") and the roots cannot obtain any more water. This point is called the wilting point W. Now this point lies distinctly higher than the hygroscopicity, which is the water content to which the soil dries out when exposed to the air, even with a quite high relative humidity of the air. But the roots cannot obtain this water. (M-W) is thus the greatest quantity of water in the soil available for the plant. But even this is not very definite, because M and W differ from horizon to horizon in the soil, and even within a single somewhat thicker horizon. So it will be necessary to determine, say

266. R. K. Schofield, The pF of the water in the soil, Transact. 3rd Intern. Congr. Soil Sc. Oxford (1935), Vol. II, pp. 37-48.

Photo by L. P. de Bussy

Fig. 255. A Madoera landscape with many palmyra palms (Borassus flabellifera) on the slope of one of the limestone ridges.

Photo by L. P. de Bussy

Fig. 256. Cart road in Madoera lined with wodier (Lannea grandis) In the dry season, this tree loses its leaves, as does the teak. Moreover the trunks are quite fire resistant. During the dry season these cultivated fields lie fallow.

for each decimeter from the surface downwards to the depth to which the maize roots reach, the amount (M-W), and the total amounts in order to arrive at the quantity of water "available" in a certain column of soil.

Now considering the plant, one must roughly know the quantity of moisture (V) which maize will transpire in the course of its development to and with the ripening of the ears. And at the same time one must know the extension of its root system in the soil. Thereafter it can be seen whether V is larger or smaller than the quantity of water present in the soil within the radius to which the roots extend. If V is larger, in practice it works out to this, that the plant must remain retarded, more or less dwarfed in its development.

Finally, we must not neglect to mention something about (2) above. If the perviousness of the soil, especially in the deeper horizons, is poor, the roots of the maize can locally rapidly reach the point W, while but a little distance away the water content is still quite a good deal higher. If in a weak clay, for example, the roots can grow rapidly to that place, then the growth stagnation of the plant is still to be avoided. In heavy loam, however, it is very difficult for the roots to grow enough to reach the moisture.

It is not within the scope of this book to go farther into the related problems of plant physiology and agricultural science and experiments. I but just touch upon them here, since Madoera, excepting perhaps the northwestern corner, is an island poor in rain, with the northern coast even very poor in rain, and frequently with rainless periods of many months. There we may expect that in spite of lack of plant nutrient materials, as N and P, in many cases water is still more severely in the minimum. The many experiments undertaken with N and P fertilizers[267] show this clearly; although these experiments by preference have been undertaken in those parts of Madoera, which are relatively the least subject to drought. Even so because of direct or indirect lack of water, a high percentage of these experiments do not come out successfully, or are harmed. Moreover, most of these experiments were on paddy; a far smaller number were experiments on such crops as cassava and but seldom were experiments carried out upon maize, the most important crop for it occupies approximately 70% of the entire cultivated area

Apart from all agricultural considerations, it seems to me that the discussion above regarding the water supplying power of a soil is of value in connection with the "natural" vegetation of a region such as Madoera. In a soil well supplied with moisture, plants and trees form a forest and the roots meet each other and even grow intertwined with each other; they cannot do this in a very dry soil, for each tree is forced to use a larger network of roots to draw the necessary water from a greater root radius. It is of course true that there are trees, such as teak, which with an 800 mm. rainfall, or better said, with water taken in by the ground from an 800 mm. annual rainfall, can continue to form a "forest." These forests, however, lose their leaves in the dry season.(monsoon forest). But, if the total annual rainfall is only about 500 to 600 mm. which usually comes in quite strong showers, as much as about 200 mm. runs off over the surface, so that the land receives but about 400 mm. Therefore each tree will need at least 2 times as great an area of ground for its moisture needs. So the idea logically arises to call such a condition a tree savanna and, if it is cultivated land, park landscape (see Fig. 257, page 693). If it is a region of still less rain it will be a treeless savanna, even without the agency of man, who burns bare the forests and plains and converts them into cogonals. In east Timor, with a vegetation as shown in Fig. 106, page 271, there is not much left to burn.

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267. Cf.: Jaarversl. Landb. voorl. dienst; the same in Afd. Landbouw; the same in Prov. Oost-Java; (1915-1937)--Verslagen betr. bemestingsproeven van het Landb. Inst. van het Alg. Pr. st. v/d Landb. (1930-1937).

Photo by Kleinenberg

Fig. 257. A characteristic scene in Madoera, showing how practically all of the land is under cultivation. If this region were not cultivated it would have only a park landscape.

Madoera is one of the most notable islands of the Archipelago. Apart from the aberrant little island of Kangean, and except for the districts with the large salt pans, Soemenep, Boender, and Tordjoen, notwithstanding the continuous struggle against the drought, approximately 80% of the surface of Madoera is agricultural land. Of this agricultural land 70% is planted to maize, with a yield of about 4.3 quintals per hectare shelled maize, a yield about the same as in the Bantam region, the lowest of Java. In Kediri a yield of 14 quintals/hectare is obtained, while in Soerakarta an average of as much as 14.7 qu./ha. is usual. Java as a whole averages 10.5 qu./ha., thus 2.5 times the yield of Madoera. These figures show very clearly that Madoera is a far from productive land; and yet, if we exclude the relatively distant Kangean, more than 400 persons per km.^{2} live on Madoera, which is too many to live exclusively by agriculture. There are four economic factors which seem to make this possible: (1) Animal husbandry, especially in the drier east, even though there is not much pasture land, and what is there is poor.[268] The cattle are thin, but healthy. (2) Fruit raising in the somewhat more moist west, from which, as from the animal industry, export is possible. (3) The salt industry, which requires much labor, and (4) The possibility of periodical emigration to the opposite shore (Java) in order to work and lay something by, or only to seek food supplies (see page 680). Enlargement of opportunity along other lines is, however, also possible by increasing the yields of rice and maize, by the use of higher yielding sorts and by rational fertilizing. But--in order to come back to the point of departure--the last-mentioned factor can only be successful if water is not in the minimum. So long, however, as it still can be said by the Government[269] that as a result of the extensive deforestation the floods are high, but the normal discharge of the rivers low,

268. As cattle fodder, maize (corn) stalks play an important role.
269. F. W. Batten, Mem. v. Overg. Res. Madoera, (Dec. 1923), p. 21.

the rainfall is not benefitting the land as much as it might. Perhaps still more water can be stored in ponds; perhaps it is also possible to plant[270] certain kinds of trees on the lands not used for agriculture, trees which are adapted to withstand the dry season and at the same time to hold up water and soil. With these plantings it is also possible to satisfy other needs (firewood, cattle fodder).

In each case Madoera, as to its "natural springs of assistance," is quite close to the extreme limit of production, and thus ripe, perhaps riper than any other region in the Netherlands Indies for all sorts of "artificial means of assistance" for the improvement of the conditions of life of its inhabitants. Means of doing this would be such as receiving commercial fertilizer in exchange for the products of agriculture, or shipping, or industry.

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270. Cf.: Versl. Landb. voorl. dienst (1917), pp. 104-105.

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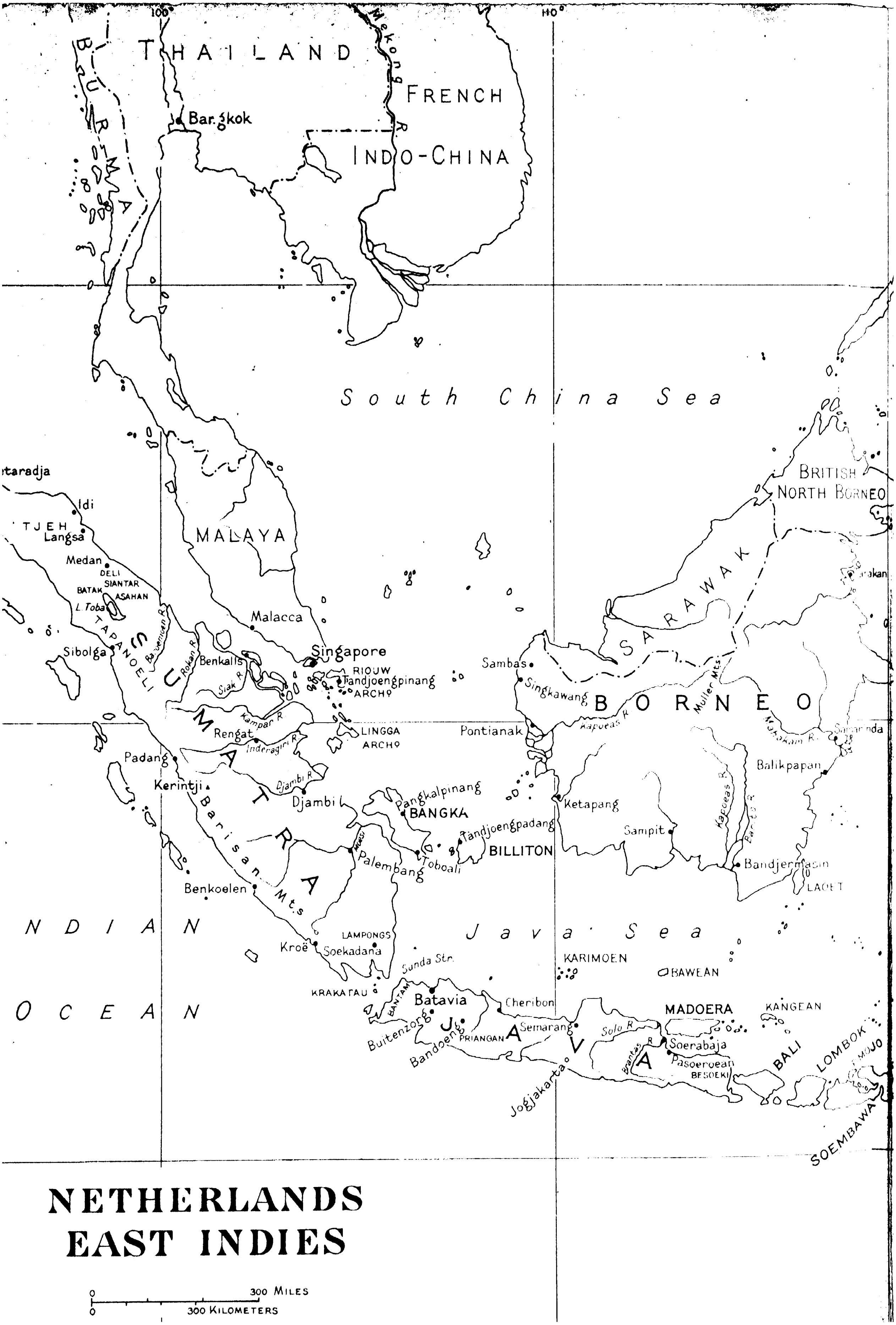

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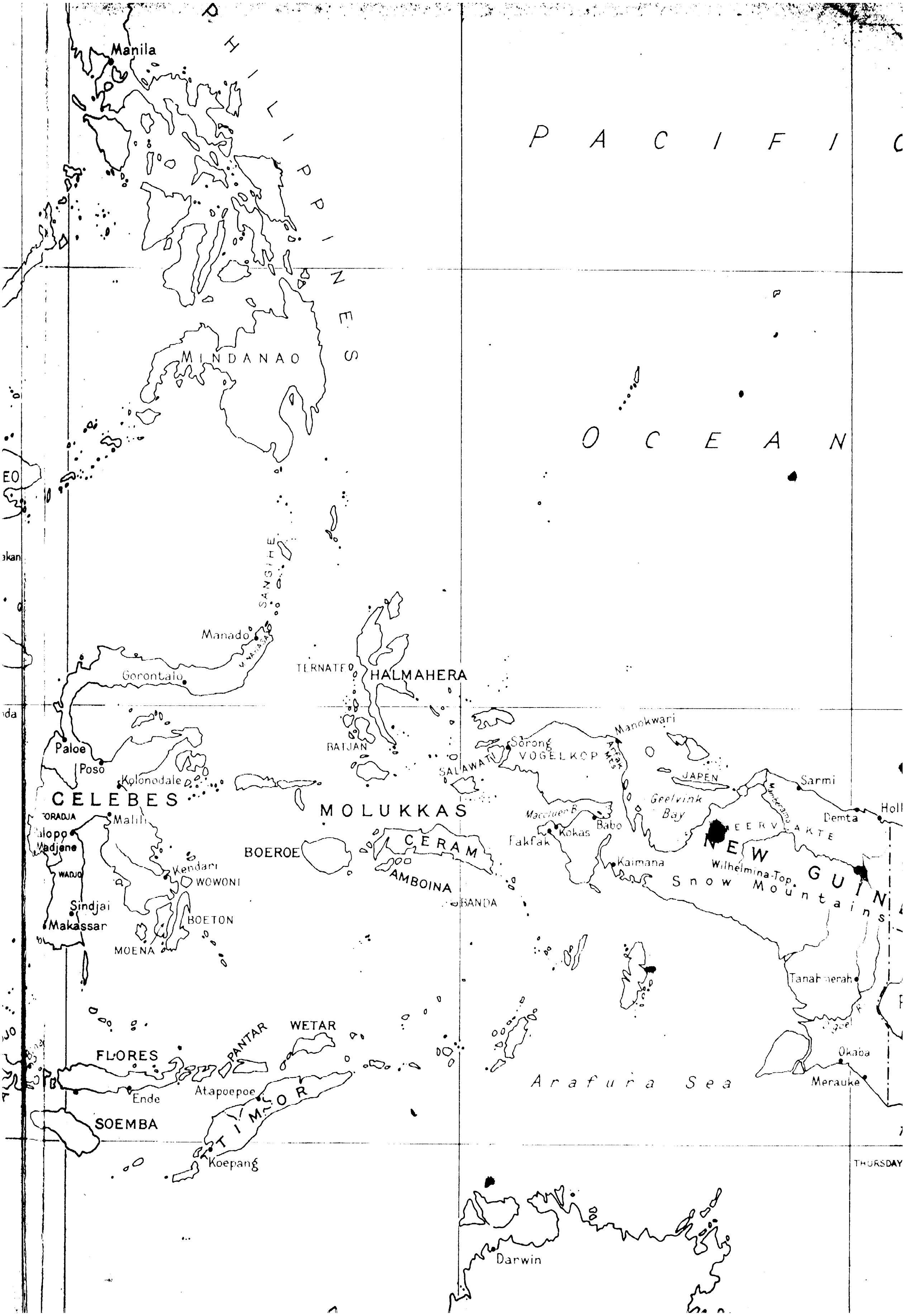
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